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Silicosis among Rock Drillers, Blasters, and Excavators in New York City, Based on a Study of 208 Examinations

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THE JOURNAL OF INDUSTRIAL HYGIENE

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SILICOSIS AMONG ROCK DRILLERS, BLASTERS, AND EXCAVATORS IN NEW YORK CITY, BASED ON A STUDY OF 208 EXAMINATIONS*

I. INTRODUCTION

OCCUPATIONAL disease has been defined as "morbid results of occupational activity traceable to specific causes or labor conditions, and followed by more or less extended incapacity for work." It was the realization of the probability that workers in New York City, engaged in drilling and excavating rock, might be exposing themselves to the development of an occupational disease, namely, silicosis, that led to the organization of the Silicosis Committee[1] to undertake a carefully planned and scientifically accurate study of the subject. It was realized in the first stages of the study that an inquiry such as was planned could be undertaken only with the co-operation as well as the guidance of all interests concerned. Aside from the organizations directly pursuing the study, it was necessary to obtain the co-operation of the officers and members of the labor unions whose workers were involved, as well as of individual employers in whose employ many of the men were to be found. This co-operation was readily forthcoming, and especially commendable has been the help rendered by individual employers and also by the secretary and officers of the General Contractors Association. Among other things, full co-operation was given in the taking

* Received for publication Nov. 16, 1928.

[1] This Committee is composed as follows: Dr. Haven Emerson, College of Physicians and Surgeons; Dr. A. Ross Smith, College of Physicians and Surgeons; Dr. A. J. Lanza, Metropolitan Life Insurance Company; Dr. Robert S. McBirney, Bureau of Industrial Hygiene, New York State Department of Labor; Mr. Harry L. Hopkins, New York Tuberculosis and Health Association; Dr. Philip S. Platt, New York Tuberculosis and Health Association; Dr. Leonard Greenburg, Yale University School of Medicine; Mr. John J. Collins, Tunnel and Subway Construction and International Union; Dr. Jacob A. Goldberg, Secretary, New York Tuberculosis and Health Association.

of dust samples, in sending workers for examination, and in publishing a statement regarding the purposes of the study in the *Bulletin* of the General Contractors Association. This co-operation may perhaps be taken as an index of the interest of the larger employers in the industry in the occupational hazards to which their workers are exposed.

It may be interesting to note that the workers, particularly the rock drillers and blasters, are generally aware of the industrial hazard to which they are exposed. If there be any unanimity of opinion among them, it might be expressed by the statement that they feel that if they remain in the occupation long enough they will end by dying of tuberculosis. They are not aware that an exposure of even a few years may have deleterious effects, though they fully realize that measures for their protection have not been taken.

New York City, particularly Manhattan and the Bronx, because of the considerable amount of rock excavation being carried on, and the ever-increasing work on new subways and tunnels, is faced with the certainty of a growing number of men incapacitated as a result of their exposure to high concentrations of silica dust. The pages that follow throw some light on the physical condition of the workers as well as on the conditions under which they are compelled to work. It is hoped that out of this study, and such other subsidiary studies and analyses as may be found necessary, measures may be speedily taken to reduce the occupational disease hazard, and to insure to the rock drillers, blasters, and excavators, not only better working conditions, but also adequate compensation when they become ill because of their occupations.

This study may also serve as an example of the excellent results that may follow an investigation planned and carried out co-operatively by a number of organizations and persons. The study was instigated and the physical examination of the workers carried out by the Industrial Department of the Institute of Public Health of Columbia University. The medical report was prepared by Dr. Adelaide Ross Smith of this department. The New York Tuberculosis and Health Association, in its rôle of promoter, co-ordinator, and financial agent, brought together those qualified persons who constitute the Silicosis Committee, secured from the Altman Foundation the necessary funds to conduct the study, carried out the arduous administrative details necessary to secure the workers for examination, submitted reports of the physical findings to the examinees, assisted in the preparation of the report, and plans to exert its influence to ameliorate the situation which the report reveals. Study of the dust to which the men were exposed at their places of work was coincidently made by the Laboratory of Industrial Hygiene of the Industrial Health Service, Metropolitan Life Insurance Company, and the report prepared by Mr. J. William Fehnel of this laboratory. The general introduction, the general conclusions, and the recommendations were prepared by the Silicosis Committee.

II. SILICOSIS AMONG ROCK DRILLERS, BLASTERS, AND EXCAVATORS IN NEW YORK CITY

ADELAIDE ROSS SMITH, M.D.

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INTRODUCTION

As an occupational disease, silicosis has a long history, but it is only comparatively recently, that is to say, within the past twenty-five years, that it has received intensive study. Much of the most important work with regard to it has been done in the mining regions of the British Empire, in Australia, New Zealand, New South Wales, and especially in South Africa where W. Watkins-Pitchford (1) (2) and A. Mavrogordato (3) of the Miners' Phthisis Medical Bureau have made very valuable contributions to the knowledge of its pathology and course.

In the United States the first studies of silicosis were made among the zinc miners of Missouri by Lanza and Childs, of the United States Public Health Service, whose report was published in 1917 (4). The United States Bureau of Mines, also in 1917, and again in 1921, published studies on silicosis, "miners' consumption," by Lanza and his associates, among the miners of Joplin, Mo., (5) and of Butte, Mont. (6). In 1921 and 1922 attention was called to silicosis among the granite cutters of Vermont by Frederick L. Hoffman (7) and D. C. Jarvis (7, Appendix G). More recent studies of industrial groups exposed to silicosis have been made by Riddell and Rothwell (8) in Ontario and by Kindel and Hayhurst (9) among the quarrymen of Ohio. The United States Bureau of Mines and the Metropolitan Life Insurance Company in 1927 established a permanent clinic for the study of the disease at Picher, Okla.

General Description of Silicosis

For a complete account of silicosis, reference must be made to the authoritative articles on the subject listed in the bibliography. It is essentially a fibrosis of the lungs induced by the inhalation of dust containing free silica. It therefore may occur in many industries, but is especially prevalent in hard rock metal mining, granite cutting, metal grinding, and sand blasting.

The pathologic changes in the lung in silicosis are believed to result from two causes: a blocking of the lung lymphatics by dust laden mononuclear cells plus the action of colloidal silica itself, the exact nature of which is in doubt. Gye and Purdy (10) believe that colloidal silica acts as a protoplasmic poison and Heffernan and Green (11) believe that its harmful effects are due rather to its powerful properties as a colloid. The small particles, those under 10 microns in size, are the only ones capable of penetrating the lung tissue. The disease is one of slow development, with few if any symptoms in the early stages. Later there is increasing dyspnea, leading to eventual disability. Cough

and pain in the chest may also be present. Silicosis is known to promote activity of the tubercle bacillus. Hoffman (7), in a survey made in the state of Vermont, found that the death rate from pulmonary tuberculosis among granite cutters was more than ten times as great as that among the total adult population. Kober (12) shows that the proportional death rate from tuberculosis ranges from 5.6 per cent. among lumbermen, who presumably have no exposure to dust containing silica, to 77.8 per cent. among buhrstone dressers, who are exposed to silica dust constantly in the course of their work. It is largely because of this association with tuberculosis, together with the fact that large numbers of workers are employed in trades involving exposure to silica dust, that silicosis ranks among the important (13) occupational diseases.[1]

Clinically the disease can be recognized with certainty only by means of radiographic examinations of the chest. Physical signs in the lungs are indeterminate. Silicosis tends to run a progressive course and there is evidence that progression may take place after removal from exposure, even in comparatively early stages. Mavrogordato (3) believes that such progression after the hazard has ceased is due to an infective element which may or may not be tuberculous.

[1] Compensation for silicosis or miners' phthisis as such is awarded in South Africa, Great Britain, New Zealand, Ontario, Alberta, Queensland, Western Australia, and New South Wales (14). There is no systematic compensation for silicosis or miners' phthisis as such in the United States at present although compensation for it can, of course, be secured in the five states having an all-inclusive occupational disease act.

Reason for Present Study

So far, reported studies of silicosis have been made for the most part on industrial groups in which the existence of silicosis as a hazard was deducible *a priori*. In the Industrial Department of the Vanderbilt Clinic, the occasional worker who appeared, giving a history of rock drilling in subway or tunnel construction work in New York City only and who showed on X-ray examination of his lungs well-marked evidence of silicosis, aroused speculation as to the extent to which silicosis develops under conditions of excavation and tunnel construction in this city. While it seemed possible that some of the phases of such work might duplicate mine conditions, there was considerable doubt as to whether the dust inhaled was high enough in silica content, the dust concentration sufficiently great, or the exposure for this type of worker sufficiently continuous to subject him to a real silicosis hazard. A study, however, of a representative group of men from occupations exposing them to the rock dust of Manhattan was considered worth making for the information, of whatever nature, it would give on this subject. This paper reports the results of such a study.

Scope of Study

It was the original intention to examine only men engaged in actual rock drilling but it soon became apparent that there is considerable interchange of work among rock drillers, rock men who break up rock and work in conjunction with the drillers, excavators, and blasters. It seemed log-

ical, therefore, to include all these groups in the study, especially as they are all closely associated and all exposed to the inhalation of rock dust to greater or lesser degree. It was estimated by the head of the Tunnel and Subway Construction and International Union that there are roughly 2,000 union men engaged in these occupations in New York City. Of the number of nonunion men no estimate can be made. The total number, of course, fluctuates widely, depending on the operations under way at any one time.

Men of the occupations mentioned were recruited, not without considerable difficulty and persistent effort, through contact with union leaders and employers and by personal letter. As an inducement to come, each man was told that he would receive a report on his condition. In addition to a physical examination, stereoscopic X-ray examination of the lungs was made in each case and the films were submitted to Dr. Henry K. Pancoast, professor of roentgenology of the University of Pennsylvania, for diagnosis. Examinations of sputum and of urine and Wassermann blood tests were made whenever specimens were obtainable.

The group of 230 men who presented themselves for examination appeared to be a fairly representative lot. While there were some who felt ill and came to determine the cause, these were balanced to a certain extent by others, vigorous and free from complaint, who came simply because they thought it a good idea to get examined. Temporary unemployment was the chief selective factor at work and this acted equally on all conditions of men.

Before examination a history of each man was taken in which, in addition to past illnesses and present complaints relating to the respiratory tract, special attention was paid to his industrial background so far as exposure to rock dust was concerned. Information was obtained as to his present trade and as to previous work at dusty trades. He was questioned as to the total length of time spent at work involving exposure to rock dust, the locality in which such work was done, the type of rock handled, the type of drill used, and the type of excavation where work had been carried on. In general, it was felt that the industrial information obtained was considerably more satisfactory than the medical. One could not be sure that past illnesses were remembered or accurately reported, and there appeared to be considerable reticence about discussing details of present complaints.

Type of Rock in New York and Vicinity

The chief rock formations in New York and vicinity are Manhattan schist, Inwood limestone, Fordham gneiss, and Yonkers gneiss (15). Manhattan schist which covers most of the island of Manhattan is a complex, highly variable micaceous schist which in many places is very massive and rich in quartz, and in other places more micaceous with correspondingly less of quartz. Samples taken by Fehnel (16) from eight localities where excavation work was being done, all in the Manhattan area, showed a total silica content varying from 56 per cent. to 94 per cent., and a free silica content of from less than 1 per cent. to 84 per cent.

Diagnosis of Silicosis

The diagnosis of silicosis among the men examined was based on the X-ray findings. Physical signs in the lungs were noted, but were not given diagnostic weight because of the well-known fact that in this condition they may be either absent or misleading. Watkins-Pitchford (1) in illustrating this point says that, of 541 men on the Witwatersrand who had been certified to be silicotic on the basis of lung signs and symptoms alone, 225, or 41 per cent., were later found to show no radiographic evidence of silicosis. In addition to the X-ray appearances and physical signs, attention was given to the general state of nutrition, the presence and degree of dyspnea, and the limitation, if any, of chest expansion.

The height and weight were taken in each case and the weight compared with the average weight for that height and age, according to the Metropolitan Life Insurance Company tables. The men were examined for dyspnea by taking the respiratory rate before exercise and again two minutes after thirty hops on one foot. The vital capacity was not measured, but the chest girth at the ensiform level was recorded at full inspiration and expiration.

It is not within the scope of this article to discuss the X-ray appearances of silicosis in full detail. For a complete exposition reference is made to Pancoast and Pendergrass' book "Pneumoconiosis" (17), or to the writings of other authorities on the subject. It may be said briefly that four stages in the development of silicosis are recognized by Pancoast (17). He follows in general the classification of Childs and Lanza made in 1917 except that through the influence of Riddell and Brink he has added to their three stages an earlier ante-primary stage. This stage is characterized, according to him, by a slight hazy increase in density in the central lung fields, more on the right side than on the left, or even entirely on the right side; an increase in density similar to the shadow cast by a small female breast or a well-developed pectoral muscle in a male, but below the location where such a shadow is usually found. Pancoast says of this stage: "To interpret such appearances correctly, one must be very familiar with the normal or healthy adult chest unaffected by silica inhalation. To any one familiar with silicotic chests only, the appearance might not be significant."

This ante-primary stage of silicosis is not generally included in classifications of the disease. In practically all the studies of silicosis made in the United States the first stage appearances have been considered the earliest. When all cases in this study with these early appearances, however, are classed together and compared with the cases which were definitely negative for silicosis, certain differences in the two groups are apparent which lend support to the belief that these changes, in all probability, indicate the earliest detectable effect of dust and that this should be considered the first roentgenologic stage in tracing the progress of the disease.

A later development than the ante-primary stage is the first stage, in which there is a definite increase in the hilum and trunk shadows and a promi-

nence of the linear markings. The appearances of this stage are very similar to those of chronic bronchitis, chronic passive congestion, and asthma. Cases in which there was a question of these conditions being responsible for the findings were, as far as possible, excluded from the group considered to show first stage silicosis. The second stage, most characteristic of silicosis, is recognized by a mottling throughout both lungs due to the presence of small discrete fibrotic nodules, pinhead to pea in size. In the third stage these nodules have coalesced to a great extent and areas of massive fibrosis are seen, or there may be a diffuse fibrosis with larger or smaller nodules still present. This classification into ante-primary, first, second, and third stages is purely roentgenologic, based on the pathologic changes which have occurred in the lung whether or not they are reflected in symptoms or in disability.

Comparison of Present Classification with South African Classification

Many different classifications of silicosis have been made, with the result that considerable confusion is likely to arise when the findings of different studies are compared. The classification most commonly used is probably that adopted by the Miners' Phthisis Medical Bureau of South Africa. Because of the extensive work on silicosis which has been done in South Africa and the important conclusions reached in regard to the rate of progression of the disease in different stages, it is important to realize the differences between the South African classification and that used in this study.

According to the South African classification (1) which has reference to clinical as well as roentgenologic findings, there are three stages: an ante-primary stage, in which it is found that the "earliest detectable specific physical signs of Silicosis are or have been present; whether or not capacity for work is or has been impaired;" a primary stage, in which it is found that "definite and specific physical signs of Silicosis are or have been present, and that capacity for work is or has been impaired;" and a secondary stage, in which it is found that "definite and specific physical signs of Silicosis are or have been present, and that capacity for work is or has been seriously and permanently impaired."

The relation of this classification to radiographic lung findings was recently made clear in an article by Riddell and Rothwell (8) in which it is stated that Dr. J. M. Smith of the Miners' Phthisis Medical Bureau had personally reviewed and classified the majority of the roentgenograms in the study. According to these authors, the X-ray appearances of the ante-primary stage by the South African classification are characteristic of silicosis and consist in a nodular mottling more or less evenly distributed throughout both lung fields. The description apparently corresponds to the fine mottling of the early second stage in the present classification. The appearances of the South African primary stage are described as, in general, the same as those of the ante-primary stage except that the individual nodules are larger and more numerous. This would still correspond to the second stage as understood in this study, in a later form. The appear-

ances of the second stage in Riddell and Rothwell's study are spoken of as corresponding to massive fibrous replacement of lung tissue; appearances essentially the same as those of Pancoast's and Childs' third stage. The ante-primary and first stages as described here are apparently not included in the South African classification which virtually begins with the second stage as understood in this study.

Incidence of Silicosis

Two hundred and thirty men were examined and X-rayed, but twenty-two cases were discarded owing to unsatisfactory lung films, leaving a total of 208 for complete study. On the basis of Pancoast's classification outlined above, of the 208 lung radiograms examined, ninety, or 43 per cent., were negative for silicosis; 118, or 57 per cent., showed evidence of it. Of these, forty-seven, or 23 per cent. of the total group of 208, were in the ante-primary stage; thirty-nine, or 19 per cent., were in the first stage; fifteen, or 7 per cent., in the second stage; and ten, or 5 per cent., in the third stage. In addition to the cases showing these more or less clearly defined stages there were seven cases, 3 per cent. of the total number in this series, in which in addition to signs of the ante-primary or the first stage there was also a general haziness suggesting that the third stage or a condition of diffuse fibrosis was developing without any intermediate second stage. In the tables throughout this article these cases showing a diffuse fibrosis type of third stage, together with the cases showing regular second and third stage changes, have been thrown together, because of their small numbers, in order to make comparison possible with the groups showing slighter changes.

The incidence of silicosis by stages in the total group of men examined is illustrated in Figure 1.

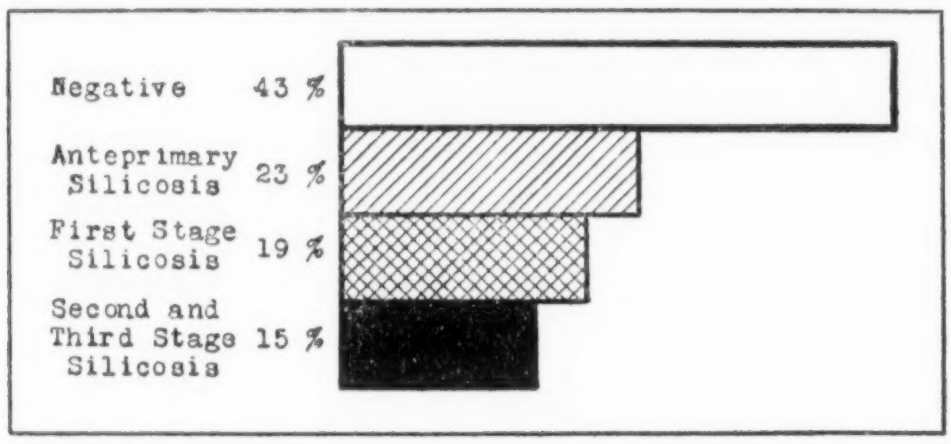

Fig. 1.—Incidence of silicosis by stages in total group of 208 men examined.

It is difficult to compare the incidence of silicosis as found among these rock drillers and excavators with that found in other studies because of differences in classification. Kindel and Hayhurst (9), for instance, found an incidence of approximately 30 per cent. of cases of silicosis among a group of 917 sandstone quarry workers in Ohio. No ante-primary cases were recognized in their study, however, and a group comprising about 26 per cent. of the total number, which showed changes corresponding to the

first stage in the present study, was not included in the estimate. The 30 per cent. of cases of silicosis in the Ohio study would therefore approximately correspond only to the 15 per cent. of cases advanced beyond the first stage in this study.

Robertson (18) found among 2,980 miners in the gold fields of Kalgoorlie, Western Australia, 22 per cent. showing silicosis in an "early" or an "advanced" stage including those in which tuberculosis was present. Here again it is probable that the stages mentioned correspond with the second and third as used in describing the cases here reported.

Lanza and Childs (4), in their study of 720 miners in Missouri, found an incidence of 74 per cent. of cases showing first, second, and third stage changes as compared with the 34 per cent. showing such changes in this study.

Riddell and Rothwell (8), examining in Ontario a group of 1,487 men from a number of different dusty trades, most of whom were exposed to dust containing silica, found a total of only 5 per cent. to be silicotic.

General Description of Group Examined

Country of Birth

By birth the group examined was predominantly North American. One hundred and two, or 49 per cent., were born in the United States; eighty-seven, or 42 per cent., of native stock. Seventy-three, or 35 per cent., were Italian born of native parentage, and twenty-five, or 12 per cent., were Irish born of Irish stock. The remainder were distributed as to nativity throughout various countries of Europe and South America.

Age, Marital State, and Race

The age distribution of the men examined, for the total group and for those showing the various stages of silicosis, is shown in Table 1.

Thirty-six, or 17 per cent. of the entire group, were under 30 years of age. One hundred and forty-four, or 69 per cent., ranged from 30 to 55 years of age and twenty-eight, or 13 per cent., were 55 years or over.

In general a correlation is shown between age and stage of silicosis. Thus among the men showing no evidence of silicosis the largest proportion fell in the 25 to 29 year age group. Among those with ante-primary silicosis the largest proportion were 30 to 34 years of age, and among those with first stage changes there were more in the 50 to 54 year age group than in any other. One-fourth of the men with second or third stage changes fell in both the 40 to 44 and the 55 to 59 year groups.

Seventy per cent. of the men were married. Slightly more than one-third of them were colored. No excessive incidence of silicosis was found among the colored workers. On the contrary, eighty-three, or 61 per cent. of the 136 white men, had silicosis in some form, while it was found in thirty-six, or 50 per cent., of the seventy-two colored men. The difference between the incidence of silicosis among the white and the colored workers may have been due to the fact that the colored men were, on the whole, slightly younger than the

white men and had a slight difference in their favor in the length of time they had been exposed to rock dust. among the men who had worked only in New York City than among those who had worked elsewhere as well.

TABLE 1.—STAGES OF SILICOSIS IN RELATION TO AGE OF MEN EXAMINED

AGE GROUP	TOTAL MEN EXAMINED				NEGATIVE		ANTE-PRIMARY SILICOSIS		FIRST STAGE OF SILICOSIS		SECOND AND THIRD STAGES OF SILICOSIS	
	No.	% Distribution	No. Silicotic	% Distribution	No.	% Distribution	No.	% Distribution	No.	% Distribution	No.	% Distribution
Totals	208	100.0	118	100.0	90	100.0	47	100.0	39	100.0	32	100.0
yrs.												
20–24	8	3.9	2	1.7	6	6.7	0	0.0	2	5.1	0	0.0
25–29	28	13.5	8	6.8	20	22.2	2	4.3	5	12.8	1	3.1
30–34	35	16.8	19	16.1	16	17.8	15	31.9	3	7.7	1	3.1
35–39	31	15.0	16	13.6	15	16.7	8	17.0	6	15.4	2	6.2
40–44	31	15.0	17	14.4	14	15.5	5	10.6	4	10.2	8	25.0
45–49	23	11.0	18	15.2	5	5.5	8	17.0	3	7.7	7	21.9
50–54	24	11.5	16	13.6	8	8.9	5	10.6	8	20.5	3	9.4
55–59	19	9.1	15	12.7	4	4.4	3	6.4	4	10.2	8	25.0
60–64	6	2.8	5	4.2	1	1.1	0	0.0	3	7.7	2	6.2
65 and over	3	1.4	2	1.7	1	1.1	1	2.1	1	2.6	0	0.0

Locality of Work

While many of the men examined had worked in a variety of places, on the whole the group reflected the effect of New York City excavating conditions. The great majority of the men had worked in New York at some time and ninety-eight, or 47 per cent., had never worked elsewhere. A comparison of the incidence of silicosis in this exclusively New York City group and in the group which had worked elsewhere as well as in New York is shown in Table 2.

It will be seen that there was a somewhat higher rate of first stage and of second and third stages of silicosis

Length of Exposure to Dust

The men were accepted as they came, without any qualifications as to the length of time they had been engaged in work exposing them to rock dust. It was thought that without a minimum time limit a truer perspective would possibly be obtained. The time spent at all dusty occupations, *i.e.*, drilling, excavating, or blasting, as recorded in the histories, is given in Table 3 for the entire number and for those showing silicosis in the various stages.

From this table it may be seen that seventy-six men, or 36.5 per cent., had been exposed less than ten years,while

132, or 63.5 per cent., had been exposed ten years or more. The shortest exposure in the entire group was six weeks; in the ante-primary group it was three years; in the first stage group it was one year, and in the second and third stage group it was nine years. The longest exposure in the entire group was forty-six years. In the ante-primary group it was forty years; in the first stage group, forty-six years and in the second and third stage group, forty-four years.

It must be remembered that the time of exposure given in Table 3 does not represent time spent continuously at work. Allowance must be made for periods of unemployment.

TABLE 2.—LOCALITY OF WORK IN RELATION TO INCIDENCE OF SILICOSIS

LOCALITY OF WORK	TOTAL MEN EXAMINED					ANTE-PRIMARY SILICOSIS			FIRST STAGE OF SILICOSIS			SECOND AND THIRD STAGES OF SILICOSIS		
	No.	% Distribution	No. Silicotic	% Distribution	% of Exposed	No.	% Distribution	% of Exposed	No.	% Distribution	% of Exposed	No.	% Distribution	% of Exposed
Totals	208	100.0	118	100.0	56.7	47	100.0	22.6	39	100.0	18.7	32	100.0	15.4
New York City only	98	47.1	60	50.8	61.2	20	42.6	20.4	22	56.4	22.4	18	56.3	18.4
New York City and elsewhere	110	52.9	58	49.2	52.7	27	57.4	24.5	17	43.6	15.5	14	43.7	12.7

TABLE 3.—LENGTH OF EXPOSURE IN RELATION TO INCIDENCE AND STAGES OF SILICOSIS

LENGTH OF EXPOSURE	TOTAL MEN EXAMINED				NEGATIVE			ANTE-PRIMARY SILICOSIS			FIRST STAGE OF SILICOSIS			SECOND AND THIRD STAGES OF SILICOSIS		
	No.	% Distribution	No. Silicotic	% Distribution	No.	% Distribution	% of Exposed	No.	% Distribution	% of Exposed	No.	% Distribution	% of Exposed	No.	% Distribution	% of Exposed
Totals	208	100.0	118	100.0	90	100.0	43.3	47	100.0	22.6	39	100.0	18.7	32	100.0	15.4
yrs.																
Less than 2	6	2.9	1	0.9	5	5.5	83.3	0	0.0	0.0	1	2.6	16.7	0	0.0	0.0
2–4	38	18.3	6	5.1	32	35.5	84.2	1	2.1	2.6	5	12.8	13.2	0	0.0	0.0
5–9	32	15.3	13	11.0	19	21.1	59.4	10	21.3	31.2	2	5.1	6.2	1	3.1	3.1
10–19	47	22.6	31	26.3	16	17.8	34.0	14	29.8	29.8	11	28.2	23.4	6	18.8	12.8
20–29	63	30.3	50	42.3	13	14.4	20.6	20	42.6	31.7	12	30.8	19.0	18	56.2	28.6
30–39	13	6.3	11	9.3	2	2.2	15.4	1	2.1	7.7	5	12.8	38.5	5	15.6	38.5
40 and over	9	4.3	6	5.1	3	3.3	33.3	1	2.1	11.2	3	7.7	33.3	2	6.2	22.2

In order to gain an idea of the steadiness or intermittency of exposure, the men were asked how many months, on an average, they had worked per year in the past five years. Two per cent. had worked five months per year or less. Sixty-five per cent. had worked, on an average, either six, seven, or eight months per year in the last five years. Thirty-three per cent. had worked nine or more months out of each of the last five years.

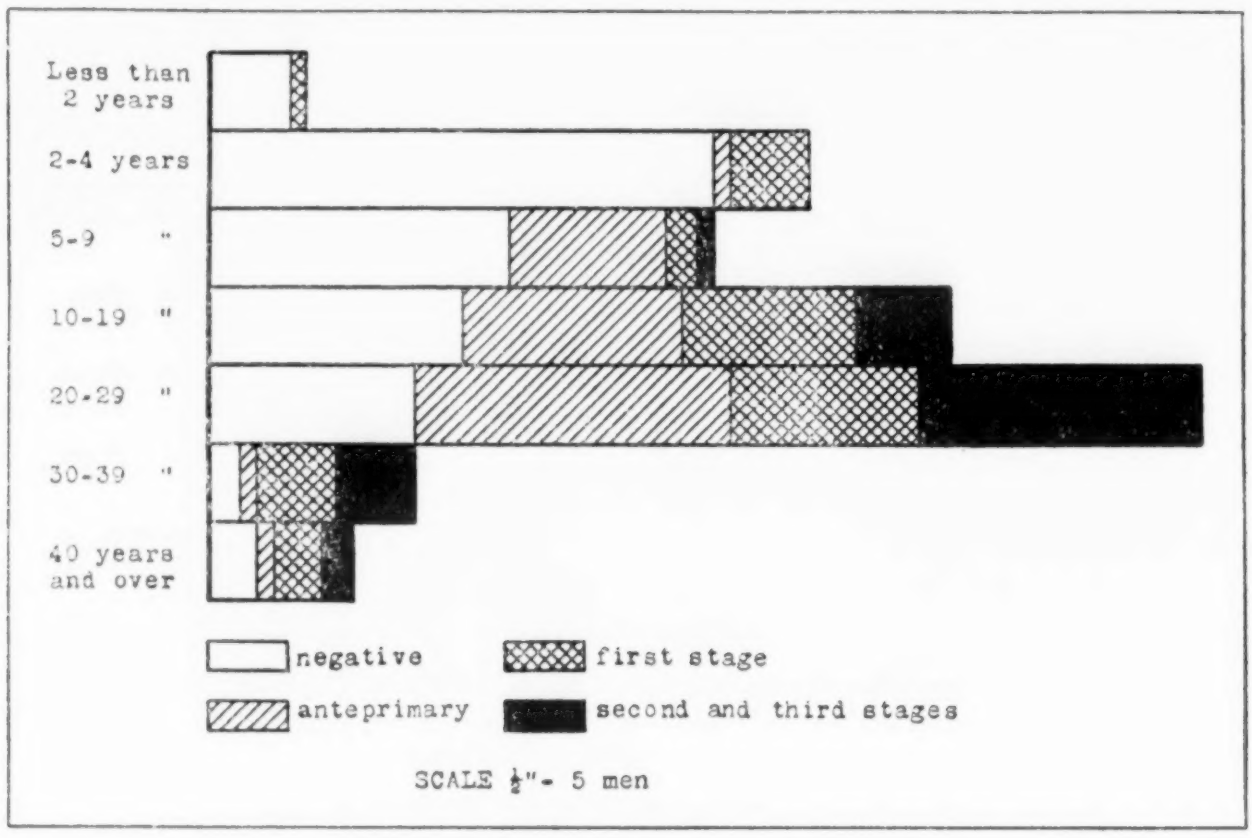

FIG. 2.—Length of exposure to dust containing silica in relation to incidence and stages of silicosis.

Figure 2 illustrates the relationship between the length of exposure to dust containing silica and the development of silicosis in its various stages. It will be seen that the proportion of negative cases is largest in the first two exposure groups and shows a steady progressive diminution as the exposure periods become longer down to the last group. Ante-primary silicosis is present in about equal proportions in the groups having exposure periods of from five to twenty-nine years. First stage silicosis, while present in the short exposure groups, becomes and remains proportionately conspicuous in the groups with an exposure of ten years or more. Second and third stage silicosis, on the other hand, is less conspicuous than first stage until after twenty years of exposure when it comes to the fore. In the last group, having an exposure of forty years and over, the proportion of advanced cases falls off slightly, indicating that these men have begun to drop out of the work.

It is apparent that the silicosis found in this study was of rather slow development. This was due chiefly, in all probability, to intermittency of exposure, since Fehnel's (16) dust studies indicate that the silica dust hazard of the work is in general pronounced.

Occupational Distribution

In respect to occupation, the total group was found to be almost equally

divided between drillers and nondrillers with a slight excess of the former. In the nondriller group were the rock men, excavators, and blasters. Twenty-six, or 12 per cent., of the total group were blasters; sixty-seven, or 32 per cent., were rock men and excavators. There is no essential difference between the work of the so-called rock men and that of the excavators. The blasters are often also drillers, though the reverse is not true. It frequently happened that men had done both drilling and excavating, or drilling and blasting, in which case they were classified as to the type of work done longest.

Table 4 presents the distribution of the three occupational groups, the drillers, the blasters, and the excavators, according to length of exposure and also gives the incidence of silicosis in each group by exposure periods.

In this study the highest incidence of silicosis occurred among blasters and the lowest incidence among excavators. Eighty-one per cent. of the blasters were silicotic as compared with 59 per cent. of the drillers and 43 per cent. of the excavators. The blasters as a group had a history of longer exposure to rock dust, however, than the other two occupational groups and the excavators, a shorter exposure. Thirty-one per cent. of the blasters had been exposed for thirty or more years, compared to 10 per cent. of the drillers and 3 per cent. of the excavators.

Blasters showed not only more silicosis (Table 4) but more advanced silicosis than the other groups, as seen in Table 5. Silicosis in the second or third stage was found in 4 per cent. of excavators, 16 per cent. of drillers,

TABLE 4.—OCCUPATION AND LENGTH OF EXPOSURE IN RELATION TO INCIDENCE OF SILICOSIS

EXPOSURE	TOTAL MEN EXAMINED					DRILLERS					BLASTERS					EXCAVATORS				
	No.	% Distribution	No. Silicotic	% Distribution	% of Exposed	No.	% Distribution	No. Silicotic	% Distribution	% of Group Exposed	No.	% Distribution	No. Silicotic	% Distribution	% of Group Exposed	No.	% Distribution	No. Silicotic	% Distribution	% of Group Exposed
Totals	208	100.0	118	100.0	56.7	115	100.0	68	100.0	59.1	26	100.0	21	100.0	80.8	67	100.0	29	100.0	43.3
yrs.																				
Under 10	76	36.5	20	17.0	26.3	43	37.4	11	16.2	25.6	4	15.4	3	14.3	75.0	29	43.3	6	20.7	20.7
10–29	110	52.9	81	68.6	73.6	60	52.2	47	69.1	78.4	14	53.8	12	57.1	85.8	36	53.7	22	75.9	61.1
30 and over	22	10.6	17	14.4	77.3	12	10.4	10	14.7	83.3	8	30.8	6	28.6	75.0	2	3.0	1	3.4	50.0

and 38 per cent. of blasters. It looks as though blasting as a job is more dominates. This type of drill, which has replaced the old steam tripod drill,

TABLE 5.—OCCUPATION IN RELATION TO STAGES OF SILICOSIS

STAGE OF SILICOSIS	TOTAL MEN EXAMINED		DRILLERS			BLASTERS			EXCAVATORS		
	No.	% Distribution	No.	% Distribution	% of Group Exposed	No.	% Distribution	% of Group Exposed	No.	% Distribution	% of Group Exposed
Totals	208	100.0	115	100.0	55.3	26	100.0	12.5	67	100.0	32.2
Negative	90	43.3	47	40.9	52.2	5	19.2	5.5	38	56.7	42.2
Ante-primary silicosis	47	22.6	28	24.3	59.6	5	19.2	10.6	14	20.9	29.8
First stage	39	18.7	21	18.3	53.8	6	23.1	15.4	12	17.9	30.8
Second and third stages	32	15.4	19	16.5	59.3	10	38.5	31.3	3	4.5	9.4

hazardous than drilling but since exposure periods for the two types of work differ it is impossible to reach a definite conclusion. The same difficulty is met in drawing a conclusion about the relative hazard of excavating and drilling. The excavators showed least silicosis, but they also had as a group a shorter exposure.

Type of Drill Used

Ninety-one per cent. of the drillers had, according to their statements, worked in hard rock only. Their reports in the matter must, of course, be regarded as giving approximate rather than accurate information. It was found that among them the men who had worked only with a dry drill greatly outnumbered those who had used only a wet drill, there being 39 per cent. of the former to 8 per cent. of the latter; sixty men, or 52 per cent., had used both. Both types of machines are used in New York City but the dry jack hammer drill pre-

is employed in open cuts, "cut and cover" work, and tunnels, while the wet drill is commonly used in driving a tunnel through solid rock where the arch and top must be drilled as well as the sides. Many of the men who were familiar with the old tripod drill believed that the change to the dry jack hammer had been for the worse as far as working conditions were concerned. They complained that the new drill created more dust and, being short, brought their faces closer to the source of the dust.[2]

Type of Excavation Work

The type of excavation work done was of three sorts: ordinary open excavating such as precedes building

[2] The jack hammer type of drill is not necessarily a dry drill. It is made with both a solid steel drill shaft and a hollow steel shaft, through which water or air or both may be applied. In South Africa, dry drilling has been prohibited by law since 1921. When solid steel drills are used, water is supplied by an accessory hose (3, p. 68).

construction, tunnel excavation, and "cut and cover" work such as is seen in subway construction where the cut is covered with boards. Some of the men had done tunnel work under compressed air and some had done mining, elsewhere of course than in New York City. Most of them had engaged in combinations of two or more of the foregoing types of work.

Open excavating above ground might, on the face of it, appear relatively free from serious hazard because of presumable air currents carrying dust away. Much depends, however, on whether the excavation is in the open or is partially surrounded by high walls. That high dust concentrations occur in such places is shown by Fehnel (16). In counts made on twenty-one samples obtained from six building foundation excavations he found that the number of particles below 10 microns in size ranged from nearly seventeen million to over seventeen billion per cubic meter of air. Higher dust concentrations were shown in some of these samples than were found in the dustiest departments of the Portland cement plant reported on in United States Public Health Bulletin No. 176 (19) where the same type of dust sampling instrument was used.

There is no provision made for ventilation in tunnel or "cut and cover" work and atmospheric conditions are again entirely the result of chance, with ample opportunity for the formation of culs-de-sac with high dust concentrations. In nine samples taken by Fehnel (16) from two subway "cut and cover" excavation sites, the counts of particles less than 10 microns in size ranged from a little over two million to nearly two billion per cubic meter.

The open type of excavation work was the one most frequently listed by the men examined. Seventy-two, or 35 per cent., of the men had worked only in open excavations. Twenty-nine, or 14 per cent., listed work in open excavations and tunnels; twenty-six, or 12 per cent., each, in open excavations and "cut and cover" jobs and in open excavations, tunnels, and "cut and cover" jobs; eleven, or 5 per cent., in open excavations and mines; seven, or 3 per cent., in tunnels only; and two, or 1 per cent., in "cut and cover" excavations only. The remainder listed twelve other combinations of work.

No correlation is possible between the incidence of silicosis and the exact type of work since those who had done "cut and cover" work, for example, had also in many cases done tunnel work, mining, etc., as well.

A correlation is possible, however, between the incidence of silicosis among those who had engaged in open excavating only and that among those who had done all other types of work: namely, tunnel work, "cut and cover" work, work under compressed air, and mining.

From Table 6 it may be seen that the incidence of silicosis in all stages was, as might be expected, considerably less among those who had done open excavating only than it was among the men who had done the other types of work.

Figure 3 depicts graphically the comparative incidence of cases showing the various stages of silicosis in the two groups. Thus among those who had done only open excavating,

58 per cent. had no silicosis, 21 per cent. had ante-primary silicosis, 15 per cent. first stage silicosis, and 5 per cent. second or third stage silicosis. While among those who had done other types of work either exclusively or in addition to open excavating, 35 per cent. were free from silicosis, 23 per cent. showed the ante-primary stage, 21 per cent. the first stage, and 21 per cent. the second or third stage. It should be noted that open excavating alone produced second or third stage silicosis in 5 per cent. of the men who engaged in it. This is not surprising in view of the dust counts from open excavations mentioned above.

TABLE 6.—TYPE OF EXCAVATION IN RELATION TO STAGES OF SILICOSIS

TYPE OF EXCAVATION WORK	TOTAL MEN EXAMINED					NEGATIVE			ANTE-PRIMARY SILICOSIS			FIRST STAGE OF SILICOSIS			SECOND AND THIRD STAGES OF SILICOSIS		
	No.	% Distribution	No. Silicotic	% Distribution	% of Exposed	No.	% Distribution	% of Exposed	No.	% Distribution	% of Exposed	No.	% Distribution	% of Exposed	No.	% Distribution	% of Exposed
Totals	208	100.0	118	100.0	56.7	90	100.0	43.3	47	100.0	22.6	39	100.0	18.7	32	100.0	15.4
Open excavating only	72	34.6	30	25.4	41.7	42	46.7	58.3	15	31.9	20.8	11	28.2	15.3	4	12.5	5.5
All other types	136	65.4	88	74.6	64.7	48	53.3	35.3	32	68.1	23.5	28	71.8	20.6	28	87.5	20.6

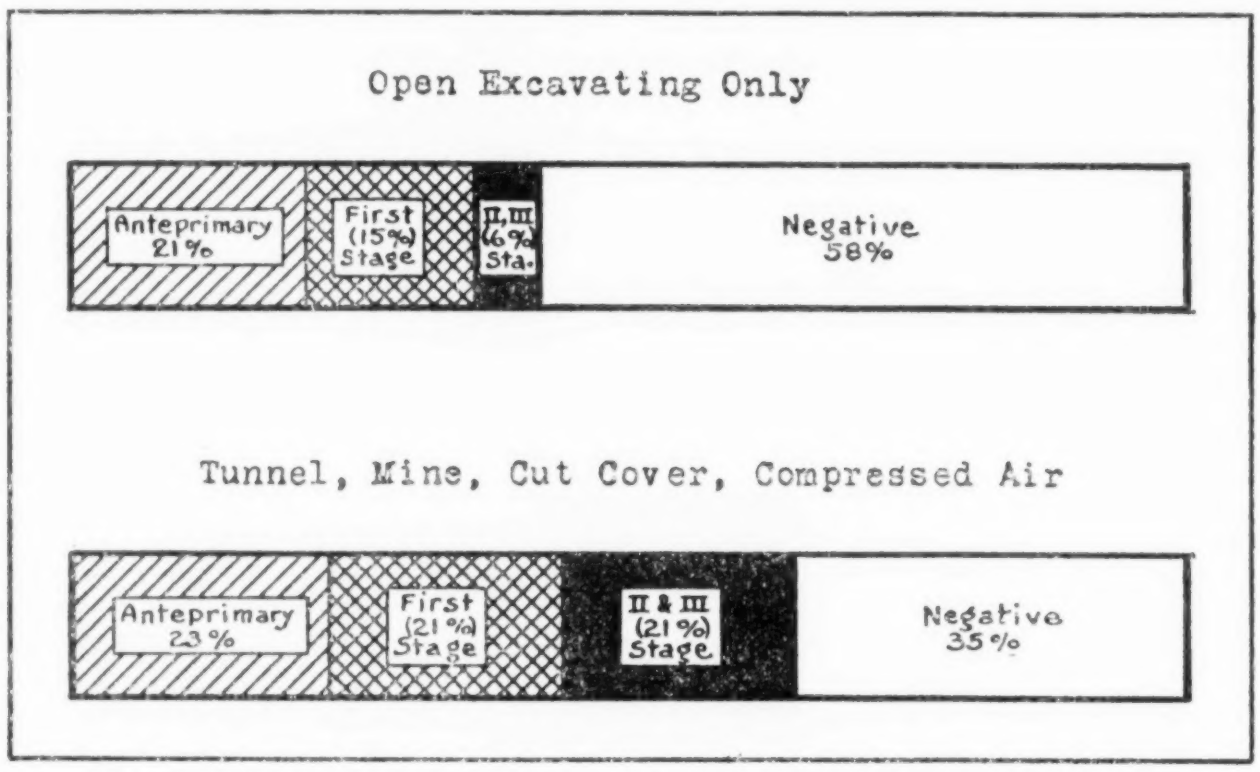

FIG. 3.—Type of excavation work in relation to stages of silicosis.

MEDICAL HISTORIES

It has already been stated that the medical histories given by these men could not be considered satisfactory.

Data obtained from the questionnaires are reported, however, for their face value.

incidence of influenza and bronchitis, the incidence of pleurisy and especially of pneumonia is definitely higher in

TABLE 7.—PREVIOUS RESPIRATORY DISEASES IN RELATION TO STAGES OF SILICOSIS

DISEASE	TOTAL MEN EXAMINED		NEGATIVE		ANTE-PRIMARY SILICOSIS		FIRST STAGE OF SILICOSIS		SECOND AND THIRD STAGES OF SILICOSIS	
	No.	%	No.	%	No.	%	No.	%	No.	%
Totals	208	100.0	90	100.0	47	100.0	39	100.0	32	100.0
Influenza	66	31.7	32	35.5	13	27.6	12	30.8	9	28.1
Bronchitis	16	7.7	8	8.9	4	8.5	3	7.7	1	3.1
Pleurisy	15	7.2	7	7.8	3	6.4	0	0.0	5	15.6
Pneumonia	30	14.4	12	13.3	3	6.4	4	10.2	11	34.4
Tuberculosis	1	0.5	1	1.1	0	0.0	0	0.0	0	0.0

TABLE 8.—INCIDENCE OF SELECTED SYMPTOMS RELATED TO RESPIRATORY CONDITIONS, BY STAGES OF SILICOSIS

SYMPTOMS	TOTAL MEN EXAMINED		NEGATIVE		ANTE-PRIMARY SILICOSIS		FIRST STAGE OF SILICOSIS		SECOND AND THIRD STAGES OF SILICOSIS	
	No.	%	No.	%	No.	%	No.	%	No.	%
Totals	208	100.0	90	100.0	47	100.0	39	100.0	32	100.0
No complaint	95	45.7	47	52.2	27	57.4	13	33.3	8	25.0
Cough	44	21.1	24	26.7	10	21.3	11	28.2	9	28.1
Expectoration	10	4.8	3	3.3	1	2.1	1	2.6	5	15.6
Hemoptysis	6	2.8	5	5.5	0	0.0	0	0.0	1	3.1
Dyspnea	62	29.8	21	23.3	11	23.4	15	38.5	15	46.9
Pain in chest	50	24.0	25	27.8	7	14.9	10	25.6	8	25.0
Fatigue	7	3.4	2	2.2	0	0.0	3	7.7	2	6.2
Loss of appetite	6	2.8	2	2.2	0	0.0	1	2.6	3	9.4
Loss of strength	8	3.9	3	3.3	0	0.0	3	7.7	2	6.2
Loss of weight	6	2.8	3	3.3	0	0.0	1	2.6	2	6.2
Night sweats	5	2.4	2	2.2	1	2.1	1	2.6	1	3.1

Table 7 presents the incidence of past respiratory disease in the group as a whole and in the negative and silicotic groups. It will be seen that while there is considerable uniformity among the various groups in the past

the group showing the second and third stages of silicosis.

The men were questioned specifically about the symptoms listed in Table 8 because of their possible relation to respiratory disease. This table

shows that in this study only dyspnea and, to a less extent, expectoration seem to bear a definite relation to developing silicosis. Fatigue, loss of appetite, loss of strength, and loss of weight were reported by a slightly larger percentage of those in the first and the second and third stage groups than in the other groups, but the actual numbers of men concerned were too small to be significant. Cough and pain in the chest, generally considered to play a prominent part in the symptomatology of silicosis, were in this study reported in approximately equal proportions among the silicotic and the non-silicotic. Eight, or 25 per cent., of the men with second or third stage silicosis reported none of the symptoms listed.

Physical Findings

Inasmuch as the men were given complete physical examinations, many data were collected which were irrelevant to the subject of silicosis and which therefore are not recorded here. In this section are presented only findings related to lung conditions and findings of general interest.

Build and Stature

In build and stature a rather heavy, stocky physical type predominated. About half the men were of standard weight; a little over a third were overweight, and less than a quarter were underweight. The proportion of underweight individuals diminished in the groups showing more advanced silicosis and was least of all in the group with second and third stage changes. About 70 per cent. of the men ranged from 5 feet, 2 inches to 5 feet, 7 inches in height.

Chest Expansion

Measurements were made of chest expansion at full inspiration and full expiration in all cases. Chest expansion even in the negative group tended to be less than is usually considered normal. Some restriction of expansion was found to be associated with silicosis beyond the ante-primary stage. An expansion of 2 inches or less was found in 55 per cent. of cases in the group showing no silicosis; in 53 per cent. of those with ante-primary silicosis; in 67 per cent. of cases with first stage changes; and in 69 per cent. of cases in the second and third stage group.

Respiratory Rate

The respiratory rate before exercise and again two minutes after thirty hops on one foot was recorded in all but twelve cases. Some dyspnea was demonstrated in this way in the second and third stage group. The rate was found to have returned after exercise to the preexercise rate, or slightly less, in approximately 85 per cent. of cases in the negative, ante-primary, and first stage groups. In the group showing second and third stage changes it had returned to the preexercise rate after exercise in 75 per cent. of cases. In all but one of the cases showing an increase after exercise the increase was no greater than 9 respirations per minute.

Vision, Hearing, etc.

In testing for myopia by the Snellen chart, forty-eight, or 23 per cent., of the men were found to have defective vision. Seven per cent. had a chronic conjunctivitis probably attributable to dust. The proportion of

men with defective hearing was large, as was natural in a group exposed to the noise of pneumatic drills and blasting. One hundred, or 48 per cent., of the entire number had some impairment of hearing. In the group of thirty-two showing second and third stage silicosis twenty-two, or 70 per cent., were partially deaf. One-quarter of the men had partial nasal obstruction, an undesirable condition presumably among those exposed to rock dust, though Jarvis (20) in studying the granite cutters of Vermont concluded that mouth breathers eliminate more dust than nose breathers. Thirty-seven, or 18 per cent., of the men showed enlarged or infected tonsils. Dental caries and pyorrhea were present in 29 and 34 per cent. of cases, respectively.

Heart Disease

Twenty-two men, or 10 per cent. of the total number, were found to have heart disease which was classified as follows according to the terminology approved by the American Heart Association:

Chronic myocarditis	6
Chronic myocarditis with enlargement	6
Chronic cardiac valvular disease	3
Enlargement of heart	4
Aortitis with dilatation	2
Arteriosclerosis of aorta	1
	22

Etiologic factors were recorded as follows: arteriosclerosis in nine cases; hypertension in eight cases; syphilis in two cases; rheumatic fever in one case; chronic nephritis in two cases; unknown in nine cases. There is a question as to whether the rather high incidence of chronic myocarditis may be related to the presence of silicosis. It seems reasonable to suppose that advanced silicosis would tend to impede pulmonary circulation and thus throw an additional burden upon the heart. The group showing second and third stage changes actually had a considerably higher incidence of heart disease than the other groups but since the factor of age enters the situation as well as the factor of silicosis it is impossible to reach a conclusion as to the etiologic importance of the silicosis. Several cases showed rather marked decompensation. In these it was impossible to form an opinion as to the presence or absence of silicosis.

The arteries showed thickening in eighty-seven cases, or 42 per cent. The blood pressure was above 150 in twenty-eight instances. Nine of these occurred in the negative group, an incidence of 10 per cent., while nineteen cases occurred among those showing evidence of silicosis, giving an incidence in this group of 16 per cent. The diastolic blood pressure was above 100 in twenty-one cases, or 10 per cent. of the entire group. Five of these cases occurred in the negative group, an incidence of 5 per cent., and sixteen of them in the silicotic group, an incidence of 13 per cent. While it is possible here too that silicosis may have been in part responsible for the increased amount of hypertension in the silicotic group, it must be remembered again that the men in this group were older and that the factor of age may have been at least partially accountable for the difference.

Lung Findings

The lung findings most frequently reported in all groups are shown in Table 9.

It is doubtful whether anything of diagnostic importance was found on physical examination of the lungs in any group except that with second and third stages of silicosis, where a higher proportion of cases with râles, diminished breath sounds, and diminished resonance was apparent. The group with first stage changes shares with the second and third stage group a higher proportion of cases with prolonged expiration than occurred in the other two groups. The ante-primary group showed no findings which were not present in approximately equal or greater proportion in the negative group except high-pitched breath sounds. This finding was reported about equally in all the silicotic groups. The lungs were entirely negative on physical examination in between 40 and 50 per cent. of cases in all groups except the last. Even in this group with advanced silicosis there were no physical signs reported in eight cases, or one-quarter of the total number in the group.

TABLE 9.—LUNG FINDINGS MOST FREQUENTLY REPORTED IN RELATION TO STAGES OF SILICOSIS

LUNG FINDINGS	TOTAL MEN EXAMINED		NEGATIVE		ANTE-PRIMARY SILICOSIS		FIRST STAGE OF SILICOSIS		SECOND AND THIRD STAGES OF SILICOSIS	
	No.	%	No.	%	No.	%	No.	%	No.	%
Totals	208	100.0	90	100.0	47	100.0	39	100.0	32	100.0
Negative	86	41.3	38	42.2	23	48.9	17	43.6	8	25.0
Râles	46	22.1	18	20.0	11	23.4	6	15.4	11	34.4
Diminished breath sounds	53	20.7	21	23.3	10	21.3	10	25.6	12	37.5
High-pitched breath sounds	18	8.7	2	2.2	6	12.8	5	12.8	5	15.6
Exaggerated breath sounds	26	12.5	17	18.9	2	4.3	2	5.1	5	15.6
Diminished resonance	60	28.8	27	30.0	10	21.3	10	25.6	13	40.6
Prolonged expiration	23	11.0	6	6.7	4	8.5	7	17.9	6	18.8

Tuberculosis

In diagnosing tuberculosis among these men it was necessary to place dependence chiefly on radiographic examination because the men would not remain under observation long enough for satisfactory clinical study and specimens of sputum were very difficult to obtain. Specimens were obtained from only six men in all, and were negative in each case. The diagnosis of tuberculosis with silicosis mainly by X-ray appearances without confirmatory evidence in the form of positive sputum or physical signs and symptoms known to be persistent presents serious difficulties and it is entirely possible both that some cases may have been overlooked and that some which were considered to show evidence of active tuberculosis might not have so proved had further investigation been possible.

In the entire series of 208 chest films, seven, or 3 per cent., showed what were believed to be definite or suspected

active tuberculous lesions. In three of these cases the physical signs probably healed, a tendency is shown toward an increase of tuberculosis in

TABLE 10.—INCIDENCE OF TUBERCULOUS LESIONS AS SHOWN BY ROENTGENOGRAM IN RELATION TO STAGES OF SILICOSIS

TUBERCULOUS LESIONS	TOTAL MEN EXAMINED		NEGATIVE		ANTE-PRIMARY SILICOSIS		FIRST STAGE OF SILICOSIS		SECOND AND THIRD STAGES OF SILICOSIS	
	No.	%	No.	%	No.	%	No.	%	No.	%
Totals	208	100.0	90	100.0	47	100.0	39	100.0	32	100.0
Active	6	2.8	2	2.2	1	2.1	1	2.6	2	6.2
Healed	13	6.2	4	4.4	2	4.3	2	5.1	5	15.6
Totals	19	9.1	6	6.7	3	6.4	3	7.7	7	21.9

strongly suggested tuberculosis; in two they were doubtful and in two negative. Sputum was obtained in only one of the cases, and was negative. Two of the cases occurred in the group showing no silicosis. One occurred in the ante-primary group; one was found in the first stage group and two in the second and third stage group, while in one case there was doubt as to whether silicosis was or was not present.

In nine instances roentgen ray findings believed to indicate a healed tuberculous process were seen and in four more instances such lesions were suspected. Four of these cases occurred in the negative group, two each in the ante-primary and first stage groups, and five in the second and third stage group. In one case physical signs and in three cases symptoms suggesting possible activity were present.

Considering the distribution by groups of all cases in which tuberculous lesions were seen, both those considered active and those considered the group showing advanced silicosis, as may be seen in Table 10.

The second and third stage group shows roughly three times as high an incidence of tuberculous lesions as is seen in any other group. The numbers involved, however, are too small to be conclusive.

In connection with the association of tuberculosis and silicosis, a comment of tremendous significance is seen in the death certificates of rock drillers for whom the Tunnel and Subway Construction and International Union paid death benefits over a period covering the last three years. Of the total of twenty-one deaths, fifteen were from pulmonary diseases, seven from lobar pneumonia, and eight from pulmonary tuberculosis.

Following is a résumé of two third stage cases among the men examined which were believed to be complicated by tuberculosis:

CASE 1.—This man, colored, aged 57 years, married, had been a rock driller and foreman in New York City for thirty-one years. His past history was negative ex-

cept for bronchitis and pneumonia twelve years ago. Since that time he had complained of cough with expectoration. He had been dyspneic for the past fifteen months. There was no history of hemoptysis, night sweats, or loss of weight.

Physical examination showed: weight 210 pounds, standard weight 176 pounds; temperature 98.6°F.; blood pressure 118/86; pulse 108; respiration 28. Hearing was markedly diminished. He had a chest expansion of $1\frac{1}{4}$ inches.

The lungs showed persistent crepitant râles with dulness at the left apex; râles at the right base. Breath sounds and resonance were diminished.

X-ray examination of the lungs showed large, apparently tuberculofibrotic areas in the right and left upper lobes with smaller areas of increased density in the bases. (See Fig. 9.)

Urine was negative. Wassermann test was negative. Specimen of sputum was not obtained.

Case 2.—This man, white, aged 62 years, a widower, had been a rock driller and blaster in Pennsylvania and New York City for thirty years. His past history was negative except for pneumonia. He complained of cough of ten years' duration with grayish expectoration. During the past three years he had been dyspneic and within the past year complained of fatigue and loss of strength. No hemoptysis, night sweats, or loss of weight were reported.

Physical examination showed: weight 146 pounds, standard weight 155 pounds; temperature 98.6°F.; blood pressure 180/104; pulse 100; respiration 24. There was markedly diminished hearing. He had partial nasal obstruction, and pharyngitis. He had a chest expansion of 1 inch.

The lungs showed diminished resonance and breath sounds, with moist and crepitant râles throughout. Bronchovesicular breathing was apparent at the apexes anteriorly.

X-ray examination of the lungs showed a diffuse mottled appearance throughout both lungs with areas of increased density in the left lower lobe. The heart was hypertrophied.

Urine showed albumin. Wassermann test was negative. Sputum was negative in two specimens.

Both of these cases illustrate the absence of many of the classic symptoms of tuberculosis which characterizes the combined condition of tuberculosis plus silicosis.

There was one case in which the X-ray appearances suggested very strongly either a neoplasm or a very unusual manifestation of tuberculosis. A résumé is given below:

Case 3.—This man, colored, aged 40 years, married, had been a rock driller for twenty years. He gave a history of bronchitis, pleurisy, and pneumonia in 1921. Since then he had been troubled with cough, dyspnea, and pain in the chest after breathing dust. During the last two to three years he had noticed fatigue, loss of strength, night sweats, and hemoptysis. He had lost 30 pounds in the past five months.

Physical examination showed a large, well-built man above the standard weight for his height. His temperature was 99°F. He was moderately dyspneic. He had a chest expansion of 1 inch.

Examination of the lungs showed diminished breath sounds of a bronchovesicular character, diminished resonance, and sonorous râles throughout.

X-ray of the lungs showed a large circumscribed area of increased density in the right lower lobe with smaller areas in the left lung, the uninvolved portions of both lungs being apparently normal.

The case is interesting because of the possible rôle played by silica dust as an irritant and as an etiologic factor in the production of a lung neoplasm.

In the entire group there were thirteen cases showing, on physical examination, pathologic lung conditions other than silicosis and tuberculosis. Nine were cases of emphysema, one of

onchial asthma, and three of chronic onchitis.

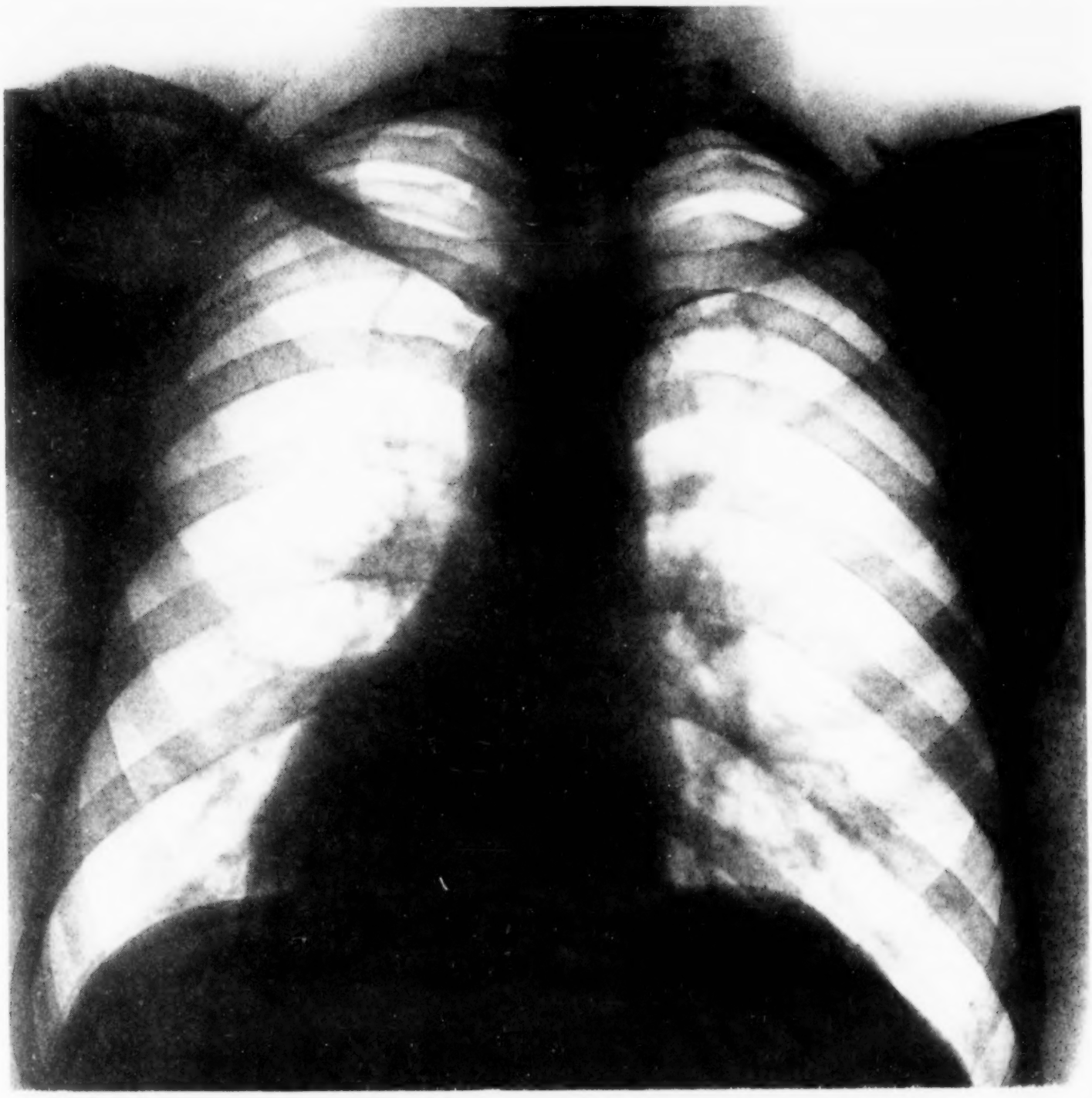

FIG. 4.—*Ante-primary silicosis.* This man, 38 years of age, had been a rock driller for eight years. The past history was negative and he had no complaints. Physical examination of the lungs was essentially negative.

Original film shows hazy appearance in the middle of the lung fields which it is impossible to reproduce.

Laboratory Findings

The urine showed albuminuria by the nitric acid ring test in ten cases, or 11 per cent., of the negative group and in seventeen cases, or 14 per cent., of the silicotic group, making a total of twenty-seven, or 13 per cent. of the entire group.

Benedict's test revealed glycosuria in eighteen cases altogether, or 9 per cent. of the total number, but in only three of these was sugar present to a marked degree.

Blood Wassermann tests were made on specimens from 148 men in the laboratories of the New York City Department of Health. An alcohol-acetone antigen was used. Of these, 127 were negative. Two were doubtful. Seven gave a 1 plus reaction, three a 3 plus, and nine a 4 plus.

This gives an incidence of definite syphilis in twelve out of 148 cases, or 8 per cent. of those examined.

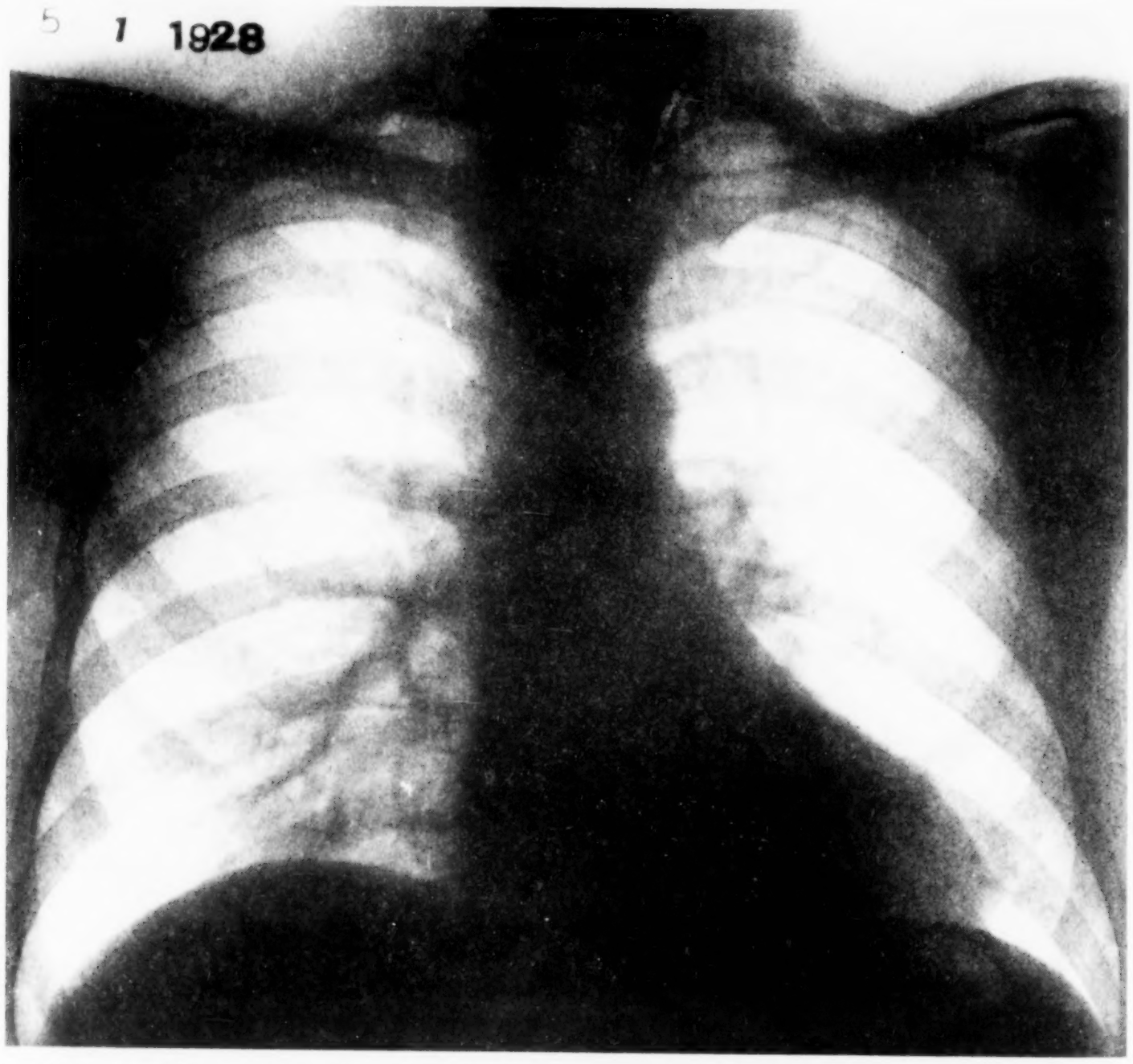

FIG. 5.—*First stage silicosis.* This man was 36 years old. He had been an excavator for two years. His past history was negative and he had no complaints relating to the respiratory tract. Physical examination of the lungs was negative. Note the increased prominence of the trunk shadows and linear markings.

X-Ray Appearances

In regard to X-ray appearances, the group showing ante-primary changes was differentiated and characterized by the slight increase in density which has already been described. This haziness was frequently seen in the right lung only. As a rule it occurred in about the middle of the lung field, sometimes in the lower portion. In a few cases the clouding was fairly evenly distributed over the entire right lung, giving a generally hazy appearance with sometimes an accentuation of haziness at the base. A typical example of ante-primary silicosis is given in Figure 4.

Many of the first stage cases showed an increase in hilum shadows, trunk shadows, and linear markings distributed more or less uniformly throughout both lungs. In others these changes were limited to one lung, usually the right, and were sometimes ac-

ecentuated at the right base. In a number of cases the cloudy appearance of the ante-primary stage was clearly

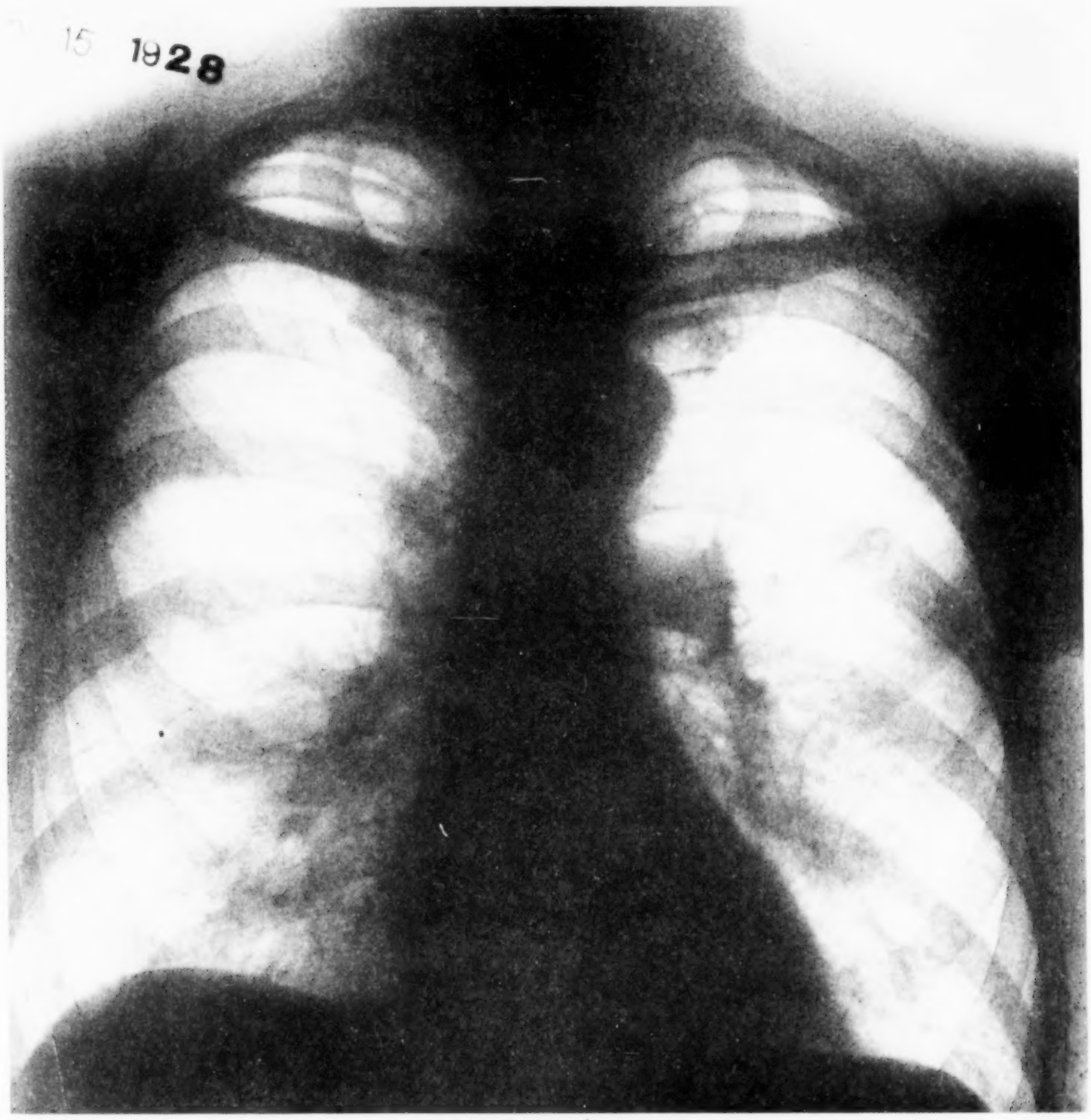

FIG. 6.—*Second stage silicosis; early.* This man was 50 years old. He had been a rock driller and blaster for twenty years in New York City. He gave a history of asthma and pneumonia. He complained of shortness of breath. Physical examination of the lungs showed marked emphysema.

Note the finely mottled appearance throughout both lungs.

visible along with the first stage changes. In two instances there was fanting of the diaphragm at the right base due to adhesions. Several cases showed a visible interlobar septum. Such an appearance is often due to pleurisy, but in these cases it was believed to be a part of the generally

increased fibrosis called forth by the inhalation of dust containing silica. Figure 5 shows a case in which the trunk shadows and linear markings of the first stage are particularly well defined.

Among the cases with second stage changes, both the finer and the coarser varieties of mottling were found. Figure 6 illustrates an early and Figure 7 a later second stage case. In one or

two cases the second stage changes appeared to be developing on the ante-

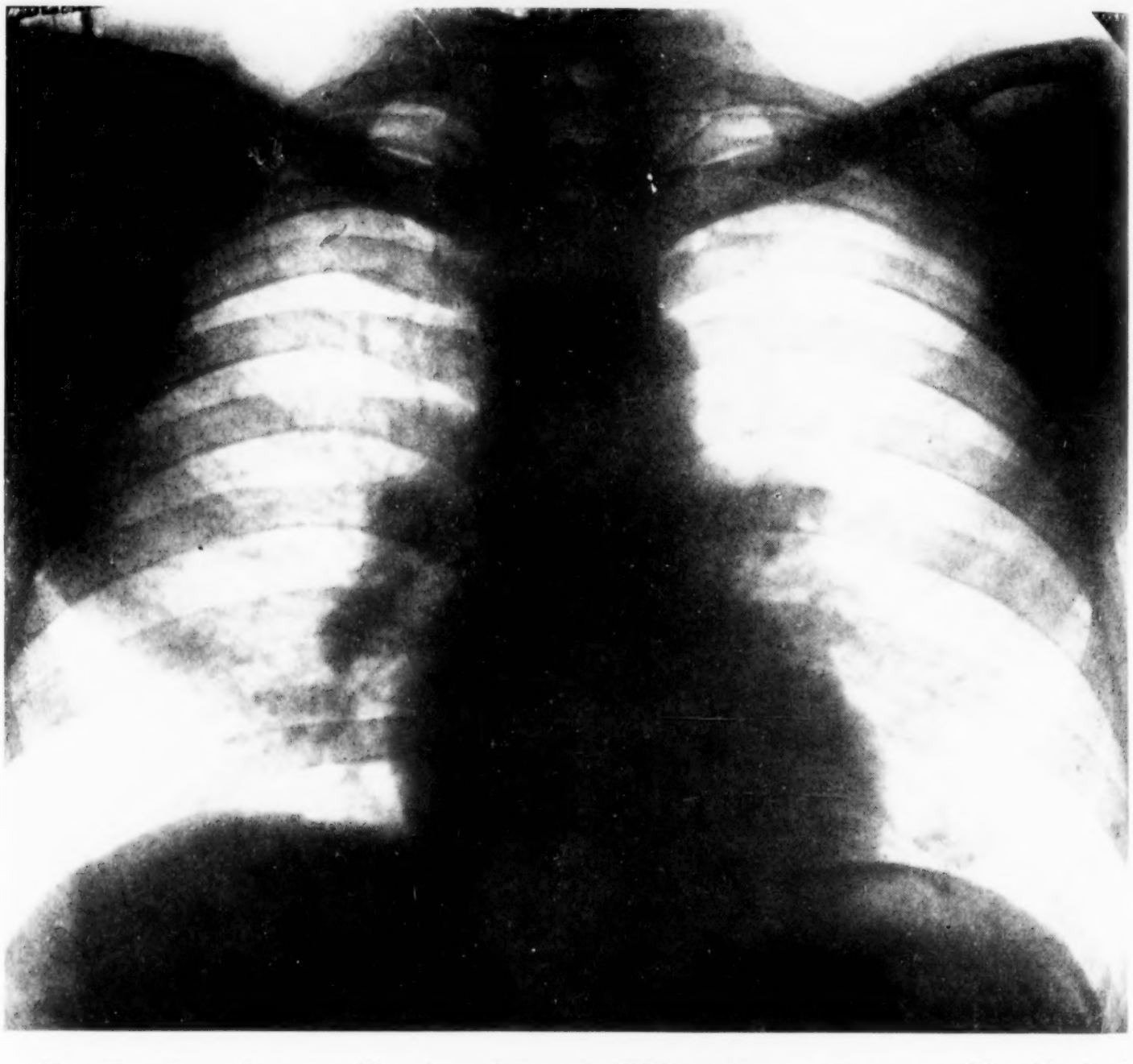

FIG. 7.—*Second stage silicosis; advanced.* This man was 39 years old. He had been a rock driller for five years and a blaster for fifteen years in New York City. His past history was negative. He complained of cough and shortness of breath. Physical examination of the lungs showed diminished breath sounds posteriorly with diminished resonance at the right base.

Note the diffuse coarse mottling throughout both lungs. The fibrotic nodules are larger than those shown in Figure 6.

primary stage without an intervening first stage.

Areas of massive fibrosis, illustrated in Figures 8 and 9, characterized the majority of third stage cases. These areas occurred for the most part in the middle fields and bases, though in one case there was a well-defined mass in the left apex. In two cases the second stage mottling was still very prominent with areas of fibrosis developing in the bases. Two cases showed a generalized fibrosis type of third stage change with the development of peripheral fans. In four instances there was marked tenting of the diaphragm.

Seven cases showed the development of a diffuse fibrosis type of the third stage, apparently without the intervention of a second stage, illustrated in Figure 10. In some cases this

was limited to one lung; in others it involved both. In three the characteristic changes of the ante-primary stage were present together with this general haziness and in four there were also the appearances of the first stage.

5 1928

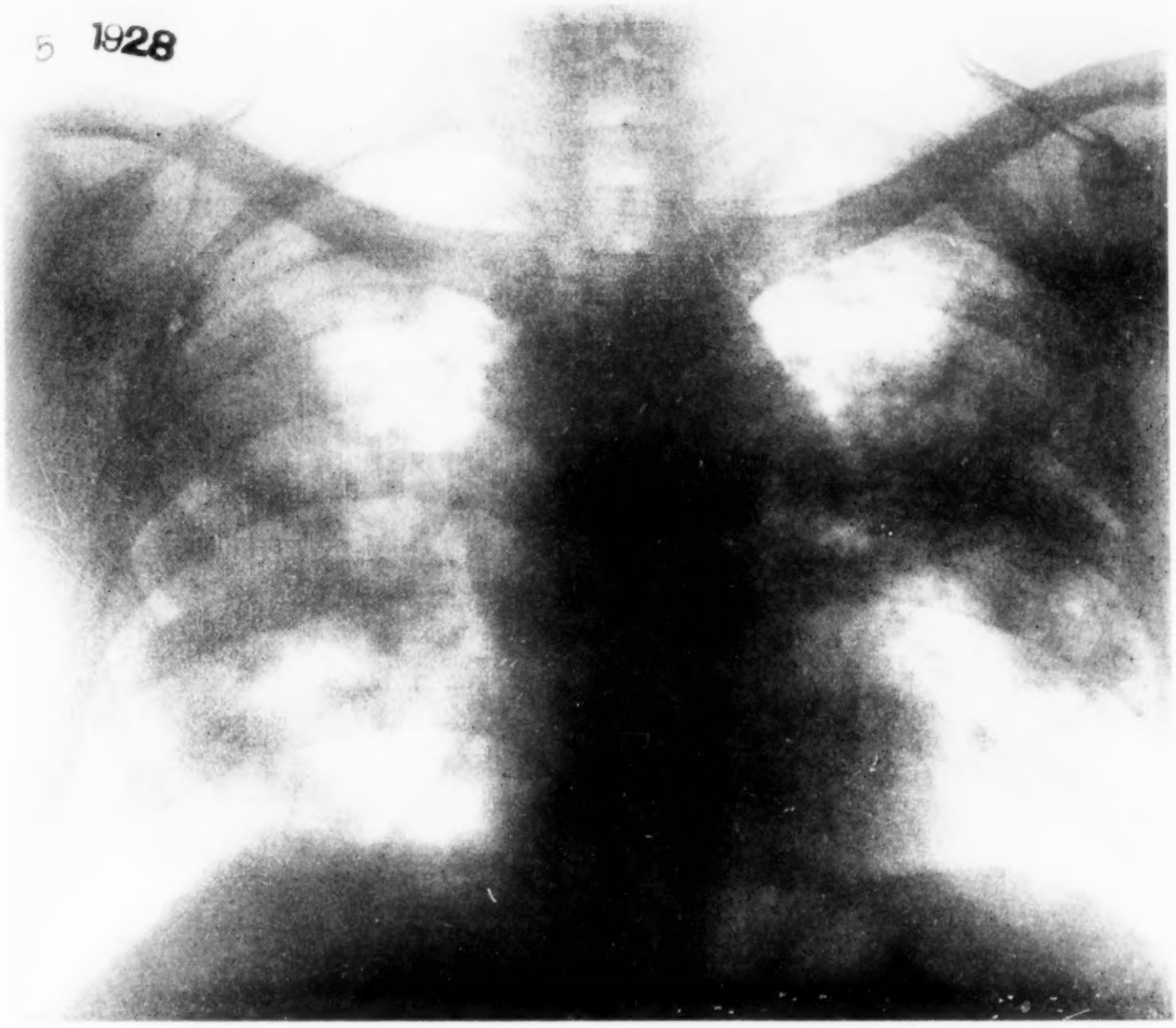

FIG. 8.—*Third stage silicosis—no evidence of tuberculosis.* This man was 45 years old. He had been a rock driller and blaster in New York City for twenty-three years. His past history was negative except for pneumonia. He complained only of pain in the chest. Physical examination of the lungs showed dulness with bronchovesicular breathing at the angle of the right scapula posteriorly.

Note the large areas of massive fibrosis extending toward the periphery in the middle of both lung fields.

Summary of Groups

In conclusion it may be well to sum up the salient facts in regard to the three groups showing silicosis in its various stages, in order to present a clear picture of the disease as found in this study.

Ante-primary Group:

The group showing ante-primary changes was the youngest of the three silicotic groups and as a whole had had a shorter exposure. It was composed of about the same proportion of drillers, blasters, and excavators as the first stage group, but more of its members had been limited in type of work to open excavating than had the members of the more advanced groups.

There was nothing in either the past histories or the present complaints of the men with ante-primary silicosis to

suggest lung disease, nor was there any apparent restriction of lung expansion or demonstrable dyspnea. The only lung finding reported more often for this group than for the non-silicotic group was high-pitched breath sounds, the diagnostic significance of which in the absence of other signs or symptoms is slight. Practically, as far as disability is concerned, this stage of silicosis is unimportant. Its significance must be considered to depend on the extent to which these changes represent the beginning of a process which will continue to progress. What the rate of progression may be is not known, because as yet no such group has been followed over a period of years.

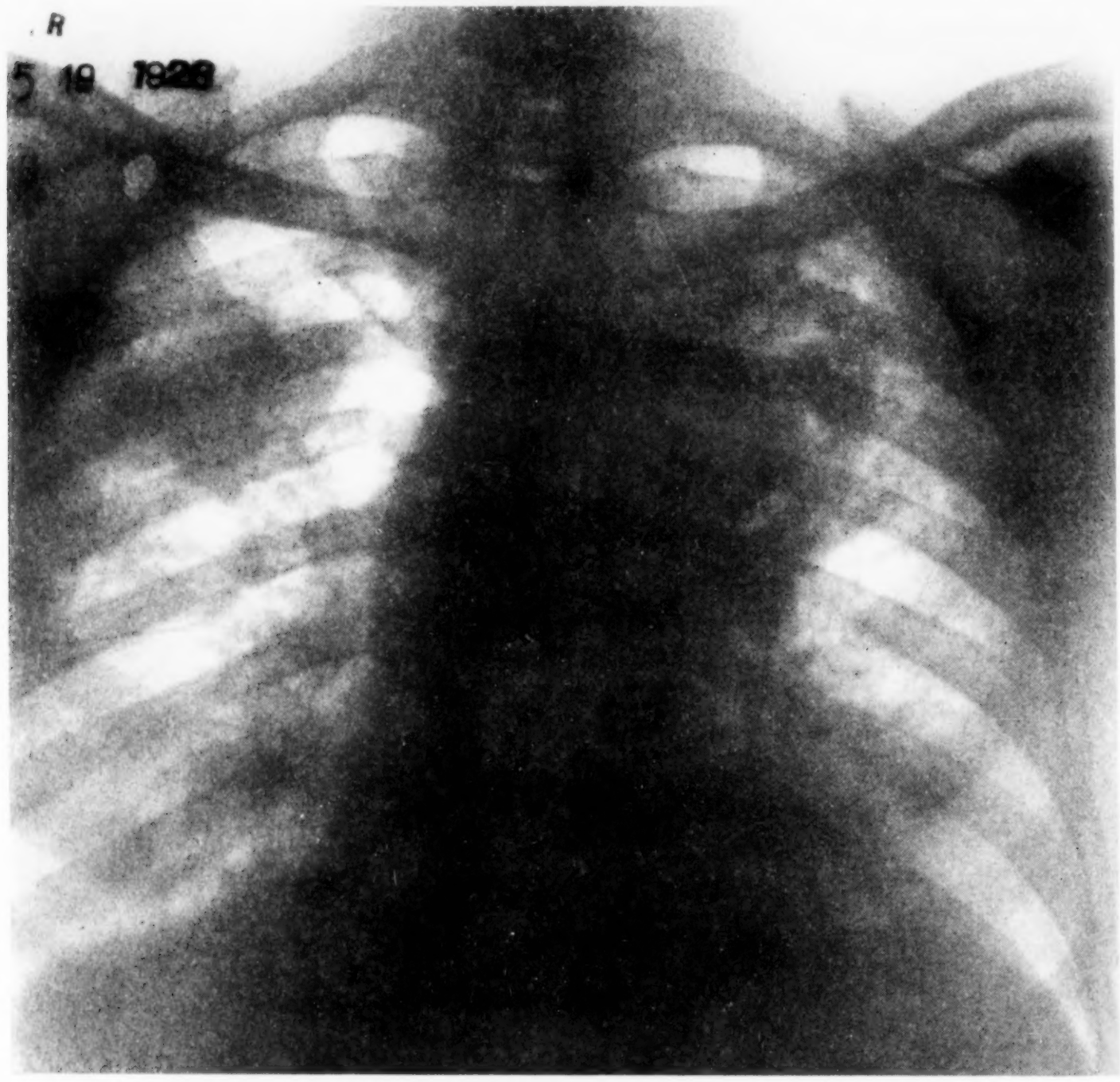

FIG. 9. *Third stage silicosis, complicated with tuberculosis.* This case history is given on page 57 (Case 1).

Note the prominence of second stage mottling with areas of increased density, showing development of third stage. Area in the left upper lobe is strongly suggestive of tuberculosis. Slight tenting of the diaphragm is seen on the right.

First Stage Group:

The group of men whose lungs showed radiographic evidence of first stage silicosis were, on the whole, older and had been exposed to rock dust longer than the men in the preceding

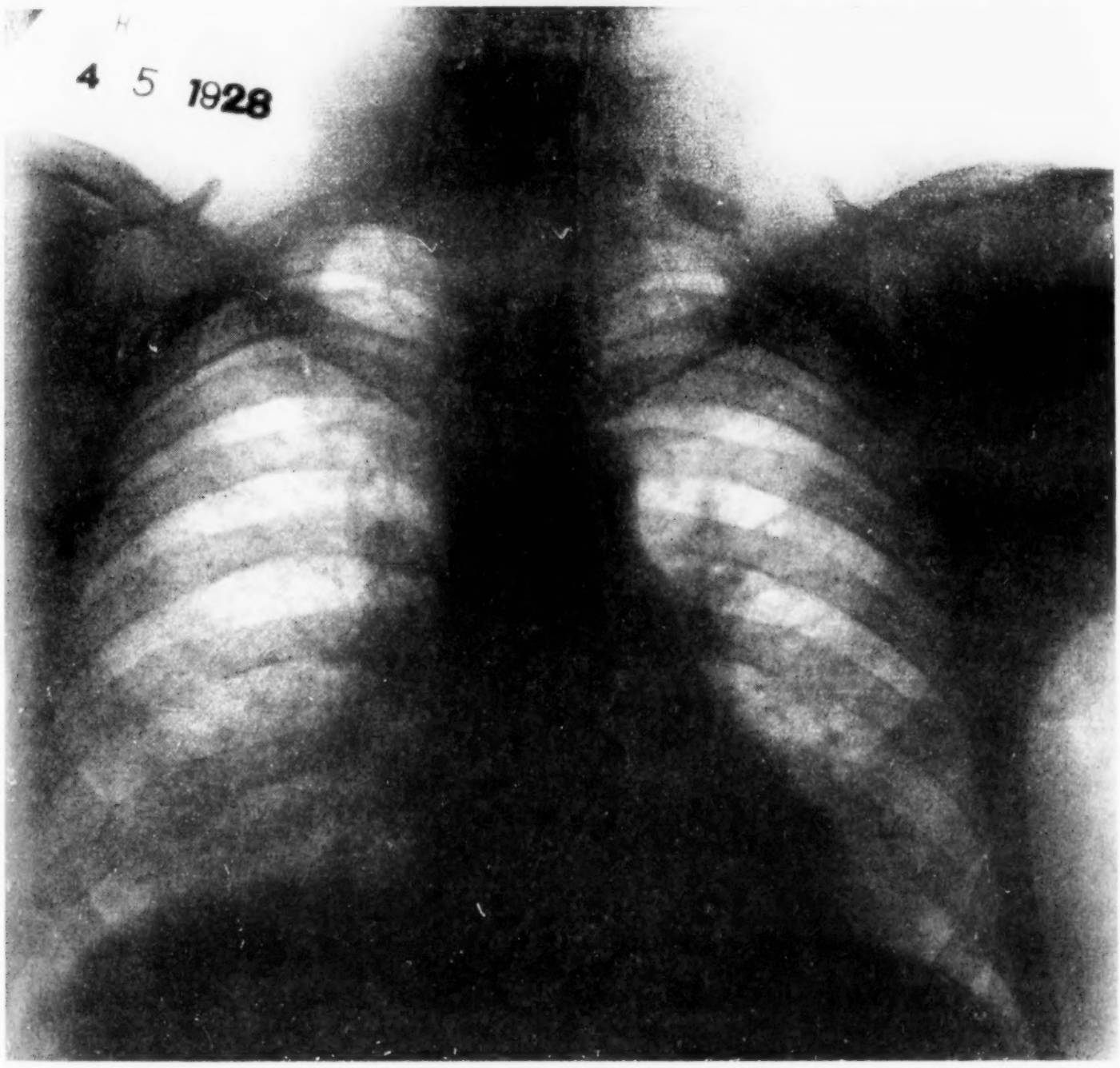

FIG. 10.—*Diffuse fibrosis type of silicosis.* This man, a negro, was 44 years old. He had been a rock driller in and about New York City for twenty-five years. His past history was negative except for influenza. He complained of pain in the chest. Physical examination of the lungs showed high-pitched, bronchovesicular breath sounds.

Note the pronounced haziness over both lungs, somewhat more marked in the right, and denser at both bases.

group. This group had practically the same proportion of excavators as the preceding group, with relatively fewer drillers and more blasters. A slightly larger proportion of the men in the first stage group had worked exclusively in New York City and had done work underground, *i.e.*, tunnel construction and "cut and cover" work, than in the group with ante-primary silicosis. There was nothing significant in their past history. Dyspnea as a complaint, however, began to appear more prominently in this group than it had in the non-silicotic and ante-primary groups, and there were more complaints of fatigue and loss of strength, though the actual numbers involved were very small.

Physical examination of the men with first stage silicosis showed slightly more men with a chest expansion of less than 2 inches than were found in the ante-primary group. Physical

signs in the lungs were not conclusive. Prolonged expiration was reported somewhat more frequently than it had been in the preceding group but was present in less than a fifth of the cases and there were as many proportionately in this group with no signs in the lungs as there were in the group showing no silicosis.

Second and Third Stage Group:

The most advanced silicotic group, it will be remembered, included fifteen men with second stage changes, ten men with fully developed third stage silicosis, and seven men with silicosis progressing to the third stage without the intervening second stage. What in this study were found to be the factors leading to the production of second and third stage changes? There was, in the first place, the factor of length of exposure. Only one of the men in the second and third stage group had been exposed less than ten years and three-quarters of them had been exposed twenty years and over. And there was, equally important, the factor of type of excavation work. All but four had engaged in underground work of some sort, the type most frequently reported being tunnel work. In occupational composition this group had more drillers and blasters and fewer excavators than the other groups.

Eighteen out of the thirty-two men in the most advanced group had worked only in New York City, the same proportion as occurred in the first stage group but a larger one than was found in the ante-primary group. Second and third stage silicosis in this study was frequently associated with a past history of pneumonia and, to a lesser extent, of pleurisy. Eight, or one-quarter of the men in the group, reported no symptoms although two of them had third stage changes. Almost half of them complained of shortness of breath and expectoration was mentioned by a higher proportion than had made this complaint in any of the other groups. Real distress, however, was apparent in only three or four. Fatigue, loss of appetite, loss of strength, and loss of weight were mentioned by two or three men each. Cough and pain in the chest did not occur any more frequently in the second and third stage group than in the other groups. It is not surprising, however, that more disability was not apparent in the second and third stage group. These were men still able to work in spite of their silicosis. The men disabled from it would not be expected to appear in a group recruited more or less directly from the job.

The men in the second and third stage group were conspicuously well nourished. Chest expansion in the group as a whole was less than in the other groups though three men with third stage changes had an expansion as great as 3 inches. The lung findings which were reported more often among these men than among the others were râles, diminished resonance, and diminished breath sounds. In one-quarter of these second and third stage cases, however, negative lung findings were reported. Radiographic evidence of tuberculous lesions, including both those considered active and those considered probably healed, was seen approximately three times as frequently among the men

with second and third stage silicosis as among the men in any of the other groups.

This last silicotic group is most significant from the point of view not so much of actual disability, which was not great among these men still on the job, as of the probable future development of these cases. Mavrogordato (3) found that on the Witwatersrand secondary silicosis (corresponding to third stage here) was nearly always a tuberculo-silicosis and that postmortem all the fatal cases disclosed pulmonary tuberculosis. He also found that silicosis in the stage corresponding to the second stage in this study showed a tendency to progress to third stage silicosis and to death from silicosis even after removal from exposure to dust. In one group of cases, showing changes corresponding to the early second stage in this study, at the end of four years after removal from dust exposure he found that 5.9 per cent. had progressed to third stage silicosis and 5.6 per cent. had died of silicosis. In another group of cases showing changes corresponding to late second stage silicosis in this study, at the end of six years after removal from further exposure, 25.5 per cent. had progressed to third stage silicosis and 25.5 per cent. had died of silicosis.

Whether or not this experience would be duplicated in other groups where silicosis had been acquired under other conditions cannot be said but there is at least the possibility that it might and, until the contrary has been proved, this gives added reason for serious attention to the prevention of the disease.

Summary

A study was made of 208 rock drillers, blasters, and excavators in New York City for the purpose of determining the incidence of silicosis among them.

Silicosis was found to be present in 118, or 57 per cent. of the men examined.

Twenty-three per cent. of the men examined showed radiographic evidence of ante-primary silicosis; 19 per cent. of first stage silicosis; 7 per cent. of second stage silicosis; and 8 per cent. of third stage silicosis.

Blasters, rock drillers, and excavators were affected by the disease in frequency and in severity in the order named.

Second and third stage silicosis occurred four times as frequently among those who had done underground work, as among those who had done only open excavating.

The incidence of silicosis among men who had worked only in New York City was slightly higher than among those who had worked elsewhere as well.

Ante-primary silicosis was found to be present in conspicuous proportions after five years' exposure to rock dust; first stage silicosis after ten years' exposure; and second and third stage silicosis after twenty years' exposure.

Second and third stage silicosis was associated to a noticeable degree with a past history of pleurisy and pneumonia.

Dyspnea and expectoration were the only symptoms found to be significantly associated with the disease in this study.

Lung signs were in general inconclusive, although râles and diminished resonance and breath sounds were found most frequently among those showing silicosis in the second and third stages.

Tuberculous lesions revealed by roentgen examination, including both those considered active and those believed to be probably healed, occurred in nineteen cases, or 9 per cent. of the total number.

The incidence of all tuberculous lesions was approximately three times as high in the group of cases showing second and third stage silicosis as in any of the other groups.

Conclusion

Silicosis constitutes a serious health hazard to rock drillers, blasters, and excavators in New York City.

The author wishes to express her gratitude to all who assisted in this study, especially to Dr. Henry K. Pancoast who interpreted the chest roentgenograms and also to Dr. Jacob A. Goldberg of the New York Tuberculosis and Health Association through whose energy material for the study was secured.

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III. A STUDY OF SILICA DUST IN HARD ROCK DRILLING IN NEW YORK CITY

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In co-operation with the Department of Industrial Hygiene of the College of Physicians and Surgeons of Columbia University and the New York Tuberculosis and Health Association, the Industrial Health Service of the Metropolitan Life Insurance Company undertook during the summer of 1928 a study of the rock dusts to which are exposed rock drillers and other hard rock workers engaged in excavation and subway construction in the Borough of Manhattan, New York City. This study was conducted by the Laboratory of Industrial Hygiene of the Metropolitan Life Insurance Company through field observations and subsequent laboratory determinations. The clinical studies of rock workers were made in the Vanderbilt Clinic and are reported upon in the preceding section.

The essential process in the work under consideration consists in drilling holes in rock with pneumatic drills, then placing dynamite in these holes and blasting the rock away. Two types of drills are used, the jack hammer and the water Leyner.

The jack hammer is a relatively small pneumatic drill, operated under an air pressure of 75 to 100 pounds. The drill steel is hollow, the air current passing through the shaft of the drill. This keeps the drill hole clean, by blowing the dust and rock particles out of the hole. As the drill operator stands leaning over the drill, the rock dust is blown into his face continually as he works. At intervals the operator "blows" the hole, by putting the full force of the air pressure through the hollow drill in order to clean out any accumulated powdered rock from the bottom of the hole. This process envelopes him in a cloud of dust.

The jack hammer is used almost entirely in drilling vertical (down)

holes and is a very efficient machine, drilling from 70 to 100 lineal feet in an eight-hour shift. There is a water jack hammer which uses water through the drill steel instead of air, but it is not much used.

The water Leyner is much heavier than the jack hammer, has to be rigidly supported upon a vertical post, requires two men to set it up, and is used mostly for drilling horizontal holes.

Methods of Air Sampling and Analysis

Samples of air were taken at the breathing levels of the drillers and as close to them as possible while they were engaged in the various operations, such as using jack hammers or water Leyners, and "mucking" (shoveling and wheeling loose rock and dirt). The Greenburg-Smith impinger (1) was used, actuated by suction obtained with a No. 1 Hancock ejector, operated by compressed air from the air lines used to operate the drills.

A flowmeter was used to measure the volume of air sample taken, usually from 50 to 100 cubic feet. Sampling was done at the rate of about 1 cubic foot per minute. The impinger was selected because of the simplicity of its operation and its accuracy in both high and low concentrations, as shown by Greenburg and his colleagues (1) (2).

The samples were collected in clean pyrex assay flasks under a 50 per cent. alcohol in water solution. The alcohol was used to prevent the fine dust particles from going into a colloidal solution. The flasks were stoppered with cleaned rubber stoppers. Samples of dust in suspension (in the alcohol-water mixture) in these flasks were transported to the laboratory and counts of the dust particles were made within twenty-four hours after taking the samples. When brought to the laboratory, the stopper was removed and carefully washed off into the flask. The contents of the flask were then filtered through a 250-mesh copper screen into a clean 500-c.c. graduated flask, so that only particles smaller than 100 microns in diameter were allowed to pass through. If the dust suspension was too dense, a further dilution was made. The contents in the graduated flask were thoroughly agitated, in order to obtain a uniform mixture, and two 1-c.c. portions were removed to Sedgewick-Rafter counting cells. After these had been allowed to settle for twenty minutes, five counts were made on each cell, one on each corner and one in the center. The lens combination was one which gave a magnification of from 85 to 110 diameters. A correction was applied for the control analysis, which consisted in deducting from the sample count the number of particles found in the control, including the number of particles present on the microscope lens. All particles over and under 10 microns in size and down to the limit of visibility were counted. A weight analysis was made by evaporating the remainder of the sample in the graduated flask to dryness in platinum and igniting to get rid of organic matter.

Variations in duplicate samples were encountered owing to air currents and rate of working of the drills.

Samples of pulverized rock were taken from the drill holes and analyzed for total and for free silica. The

methods employed were those described by Hillebrand (3), Mellor (4), and Selvig (5).

In the case of free silica determinations, the undecomposed matter was calculated as muscovite rather than as feldspar, as a microscopic examination of the rock samples showed this mineral to be in much greater concentration than orthoclase or other feldspars. The rock drilled at the locations sampled was of two varieties, a gneiss high in quartz and biotite, and a schist high in muscovite and biotite. Neither rock contained much feldspar.

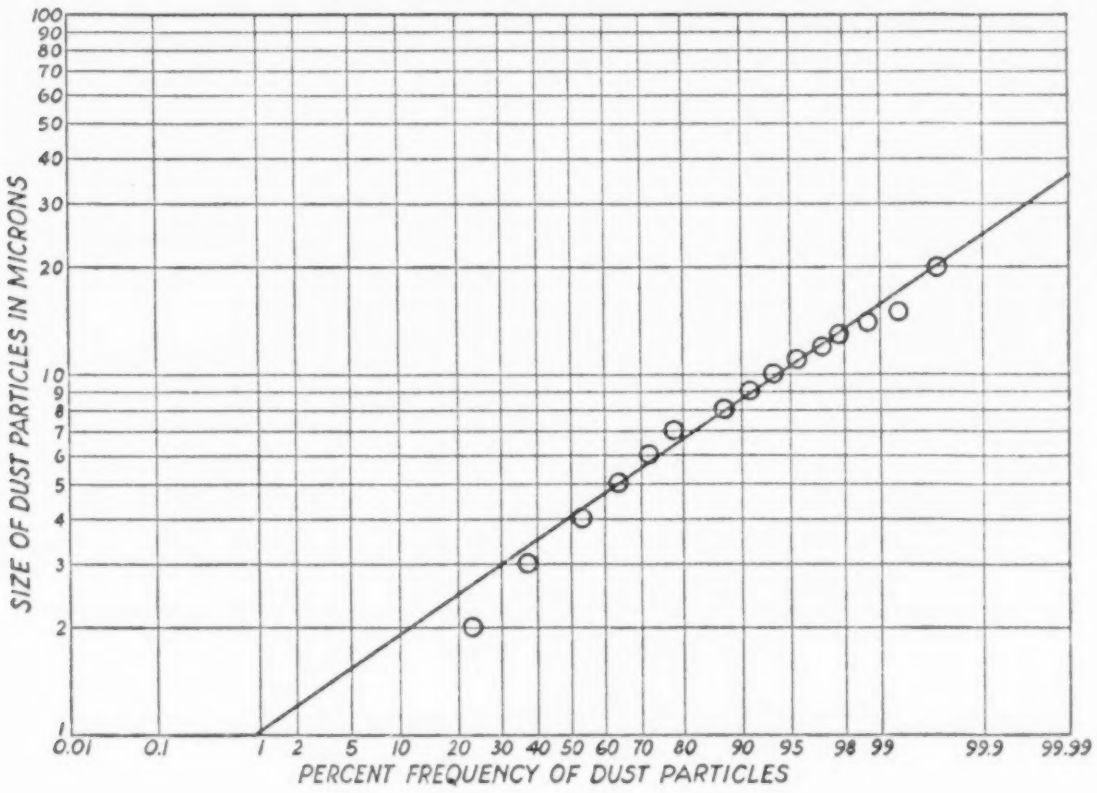

FIG. 1.—Particle size of dust in air sampled at 29th Street and 7th Avenue.

Measurements of Particle Size

Drinker (6) states that "In general problems of pneumonokoniosis, it is probable that the surface area of the particles is the most important dimension. It is mainly this dimension which accounts for variations in solubility and phagocytosis in any particular substance, and these factors appear to be responsible, in large part, for variations in the physiologic reactions from inhaled particulate matter."

Heffernan and Green (7) quote various articles to show that no particles exceeding 10 microns in greatest diameter enter the pulmonary tissue, and in their summary state that "Pulmonary silicosis is probably caused by the colloidal action of hydrated silica, formed from minute particles of silica dust disseminated through the pulmonary tissue."

Measurements of the particles in the dust collected from the air, as described above, were made by means of a microscope with an oil immersion objective and an eyepiece equipped with a filar micrometer. In plotting the size-frequency relations on Hazen's logarithmic probability paper, as in this case, the logarithms of the function measured, in microns, are plotted

as ordinates, and the probability of occurrence as abscissas (see Figs. 1, 2, and 3).

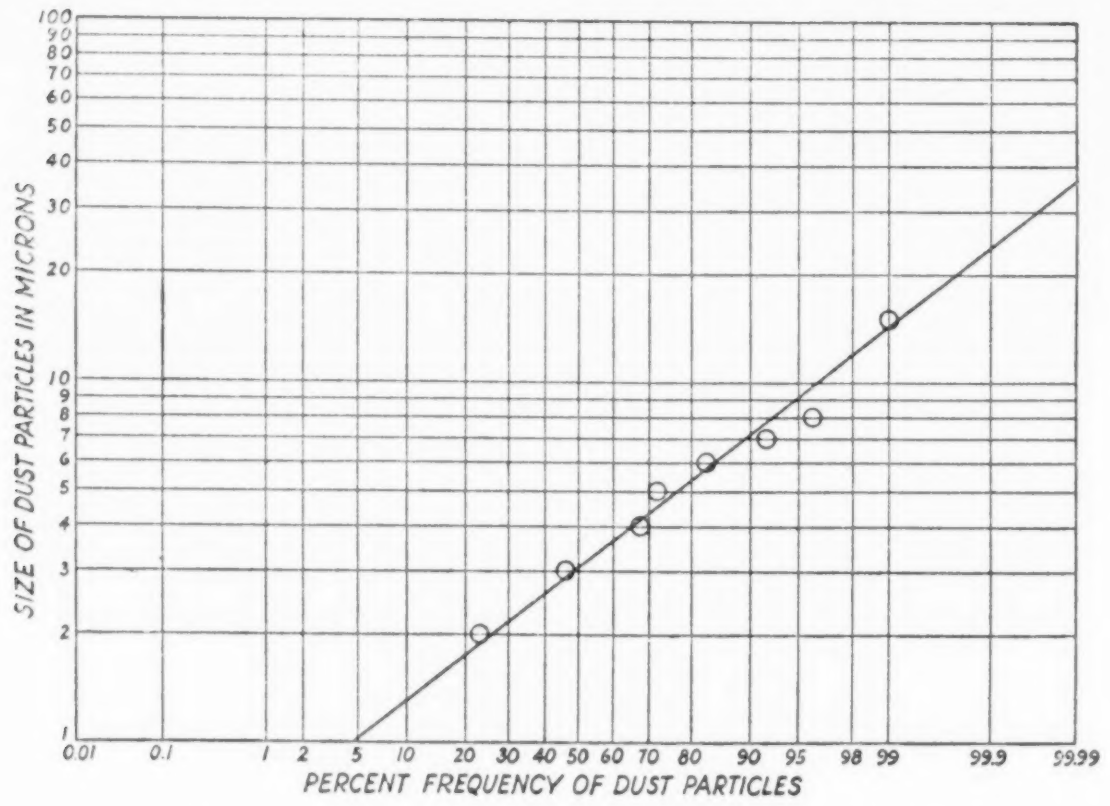

FIG. 2.—Particle size of dust in air sampled at mucking operation in subway construction work on 53rd Street.

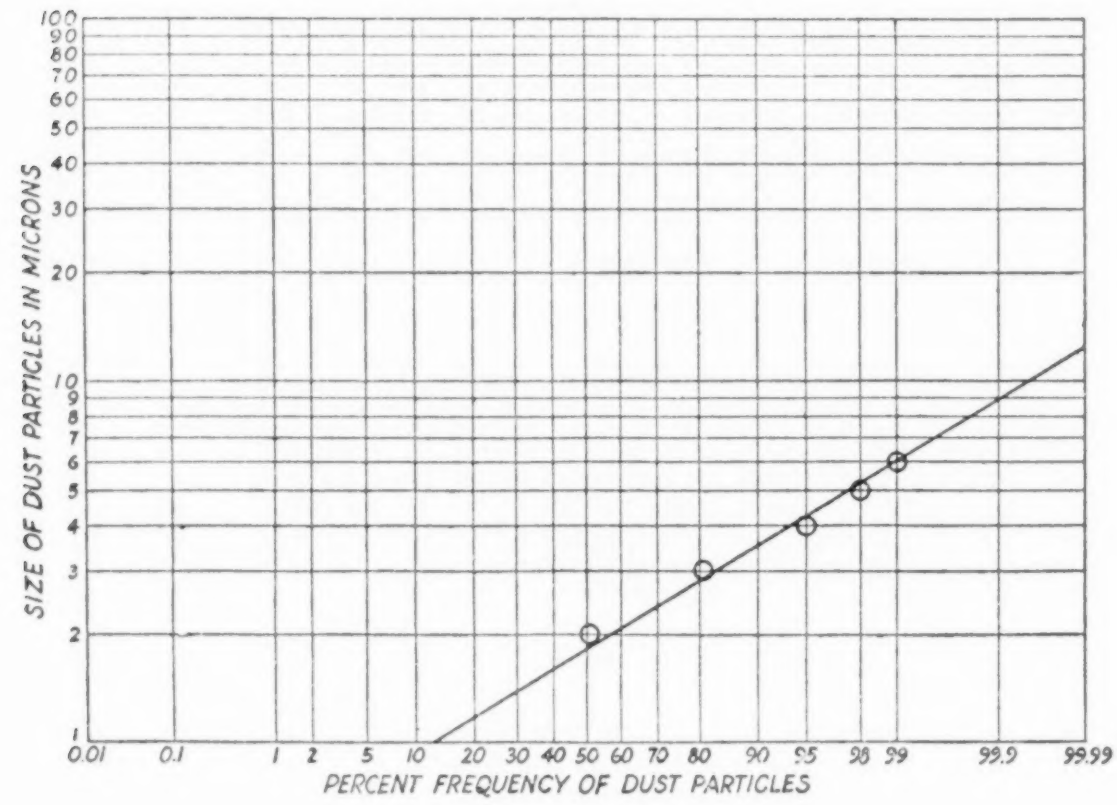

FIG. 3.—Particle size of dust in air sampled at heading in subway construction work at 176th Street and Broadway.

Locations Where Air Samples Were Taken

Thirty air samples were taken at a total of eight locations, of which six were excavations for buildings and two were in subway construction; all lying in Manhattan between First Avenue and Eighth Avenue, and between 29th Street and 176th Street. The locations and type of work were as follows:

A. 29th Street and Seventh Avenue.—This was a building foundation job, and, at the time of sampling, work had progressed to a depth of about 20 feet. This lot had a frontage of 75 feet on Seventh Avenue and a depth of 50 feet and was flanked on three sides by buildings.

Six air samples (nos. 1 to 6, inclusive) were taken alongside of the operators and at the breathing level. The weather was clear and a good wind was blowing.

B. 38th Street at First Avenue.—This building excavation operation covered a city block, fronting on First Avenue and extending from 38th Street to 39th Street and for a depth half the block between First and Second Avenues. (Samples 7, 8, and 9.) The weather was cloudy during the time that these samples were taken.

C. 43rd Street between Second and Third Avenues.—This building foundation operation had a frontage of 50 feet on both 43rd and 44th Streets and a depth of 200 feet. On either side it was flanked by tall buildings. This operation was on part of a hard rock ledge lying between 38th and 46th Streets.

One sample (no. 10) of air at a line drilling operation along the west wall was taken on a cloudy day.

D. 45th Street between Second and Third Avenues.—This was a lot with a frontage of 127 feet on 45th Street, and extending back 200 feet to 44th Street, with a frontage there of 30 feet. Two samples (nos. 11 and 12) were taken at this location. Weather was cloudy.

E. 34th Street and Eighth Avenue.—This operation fronted on the block on Eighth Avenue between 34th Street and 35th Street and extended halfway down the block toward Ninth Avenue. Air samples 13 to 16, inclusive, were taken here on a clear day.

F. 60th Street and Columbus Avenue.—This was a building excavation operation, with a frontage of 75 feet on 60th Street and a depth of 100 feet. Five air samples (nos. 17 to 21) were taken here on a clear day.

G. 176th Street and Broadway.—A shaft of part of the Eighth Avenue subway construction work was located here. Excavation was being made to provide an underground car barn and some air samples were obtained here of open cut operations at a depth of approximately 40 feet. Air samples were also taken of air at the "heading" and alongside of mucking operations. (Samples 22 to 26.) The samples were taken on rainy days.

H. 53rd Street and Second Avenue.—Here was located a shaft for the 53rd Street subway operations connecting the new Eighth Avenue subway with Long Island City. The shaft extended to a depth of 75 feet and a heading was pushed forward toward Eighth Avenue on a 12 per cent. grade. (Samples 27 to 30.) These air samples were taken on a cloudy day.

Results of Analyses

The results obtained in weighing dust samples, counting the particles, and making analyses of free and total silica are shown in Table 1. Samples 7, 8, and 9 were taken while the operator was drilling in the surface layer of Manhattan schist, composed chiefly of biotite and feldspar. Percentage frequency of dust particles is shown in Figures 1, 2, and 3.

From 95 to 99 per cent. of the silica

TABLE 1.—RESULTS OF ANALYSES OF THIRTY DUST SAMPLES TAKEN AT EIGHT LOCATIONS

I	II	III	IV	V	VI	VII	
SAMPLE NO.	LOCATION	TOTAL NO. OF DUST PARTICLES UNDER 10 MICRONS (PER CU.M. OF AIR)	WEIGHT OF DUST (UNDER 50 MICRONS) (MG. PER CU.M. OF AIR)	WEIGHT OF FREE SILICA (UNDER 50 MICRONS) (MG. PER CU.M. OF AIR)	WEIGHT OF TOTAL SILICA (UNDER 50 MICRONS) (MG. PER CU.M. OF AIR)	ANALYSIS OF DRILLED ROCK	
						Total Silica (Free and Combined) %	Free Silica %
	Dry Drilling with Jack Hammers						
	A. 29th St. at 7th Ave.:						
1	N. W. corner at 7th Ave.	5,976,114,700	213.6	97.0	153.7		
2	N. E. corner at building line	17,408,322,300	196.1	89.0	141.2		
3	Same as no. 1	4,915,146,000	141.3	64.2	101.7	72.58	45.39
4	Same as no. 2	142,949,000	4.6	2.1	3.3		
5	Along west wall	53,053,900	137.7	62.5	98.2		
6	Along west wall	8,074,449,000	148.3	67.4	106.7		
	B. 38th St. at 1st Ave.:						
7	Jack hammer operator; S. E. corner at 38th St. and 1st Ave.	211,788,000	27.2	0.0	15.3		
8	Jack hammer operator alongside of no. 7	2,598,000,000	23.7	0.0	13.4	56.40	0.01
9	Midway between 7 drillers in center of lot (see Fig. 4)	199,834,000	13.1	0.0	7.4		
	C. 43rd St. between 2nd and 3rd Aves.:						
10	West wall, line drilling	238,325,000	95.3	35.7	65.1	68.29	37.48
	D. 45th St. between 2nd and 3rd Aves.:						
11	Along west wall, line drilling	5,606,470,600	75.5	29.4	53.1	70.23	39.00
12	Center of lot	154,976,300	2.6	1.0	1.8		
	E. 34th St. and 8th Ave.:						
13	Center of operation	269,888,600	24.9	11.3	18.1		
14	West side along building wall (known as line drilling)	5,351,925,500	67.1	30.3	48.7	72.61	45.20
15	S. E. corner	6,344,460,000	63.6	28.7	46.2		
16	Pit along west wall	721,021,200	141.6	64.0	102.7		

TABLE 1.—*Continued*

	II	III	IV	V	VI	VII	
	LOCATION	TOTAL NO. OF DUST PARTICLES UNDER 10 MICRONS (PER CU. M. OF AIR)	WEIGHT OF DUST (UNDER 50 MICRONS) (MG. PER CU. M. OF AIR)	WEIGHT OF FREE SILICA (UNDER 50 MICRONS) (MG. PER CU. M. OF AIR)	WEIGHT OF TOTAL SILICA (UNDER 50 MICRONS) (MG. PER CU. M. OF AIR)	ANALYSIS OF DRILLED ROCK	
						Total Silica (Free and Combined) %	Free Silica %
	Dry Drilling with Jack Hammers—Continued						
	F. 60th St. and Columbus Ave.:						
17	Center, alongside of jack hammer operator (see Fig. 5)	126,423,000	17.3	8.4	12.7		
18	Between 2 jack hammer operators at line drilling along east wall (see Fig. 6)	89,739,000	11.7	5.7	8.6	73.62	48.59
19	Alongside of driller in pit	90,091,000	8.1	3.9	6.0		
20	General air sample...	16,975,000	10.2	5.0	7.5		
21	General air sample...	197,076,000	8.8	4.3	6.5		
	Dry Drilling with Jack Hammers and Wet Drilling with Water Leyners						
	G. 176th St. and Broadway:						
22	Jack hammer operator	252,272,500	49.4	41.6	46.2		
23	General air of cut...	37,800,800	9.9	8.3	9.3		
24	Mucking at heading.	270,238,900	42.5	35.8	39.8		
25	Mucking at heading.	86,778,200	6.4	5.4	6.0	93.60	84.29
26	5 men operating water Leyners, heading drilling....	1,804,364,900	21.9	18.5	20.5		
	H. 53rd St. and 2nd Ave.:						
27	At heading on breathing level of 5 men operating water Leyners (see Fig. 7)	136,440,000	22.2	5.7	14.3		
28		2,428,000	13.1	3.4	8.4	64.43	25.89
29	General air of tunnel.	2,872,000	6.0	1.6	3.9		
30	Mucking, 4 men.....	4,129,000	8.8	2.3	5.7		

particles are less than 10 microns in diameter. In the case of dry jack hammer drilling (Figs. 1 and 2) 50 per cent. of the silica particles are less than 3 to 4 microns in size, while in the case of wet drilling with the water Leyner (Fig. 3) 50 per cent. of the particles are less than 1.8 microns in diameter. It is evident that the use of water in rock drilling is not a solution of the dust hazard as the very small dust particles are not caught.

FIG. 4.—38th to 39th Streets at First Avenue. Air sample no. 9 taken midway between seven men in center of lot, dry drilling with jack hammers. (See Table 1.)

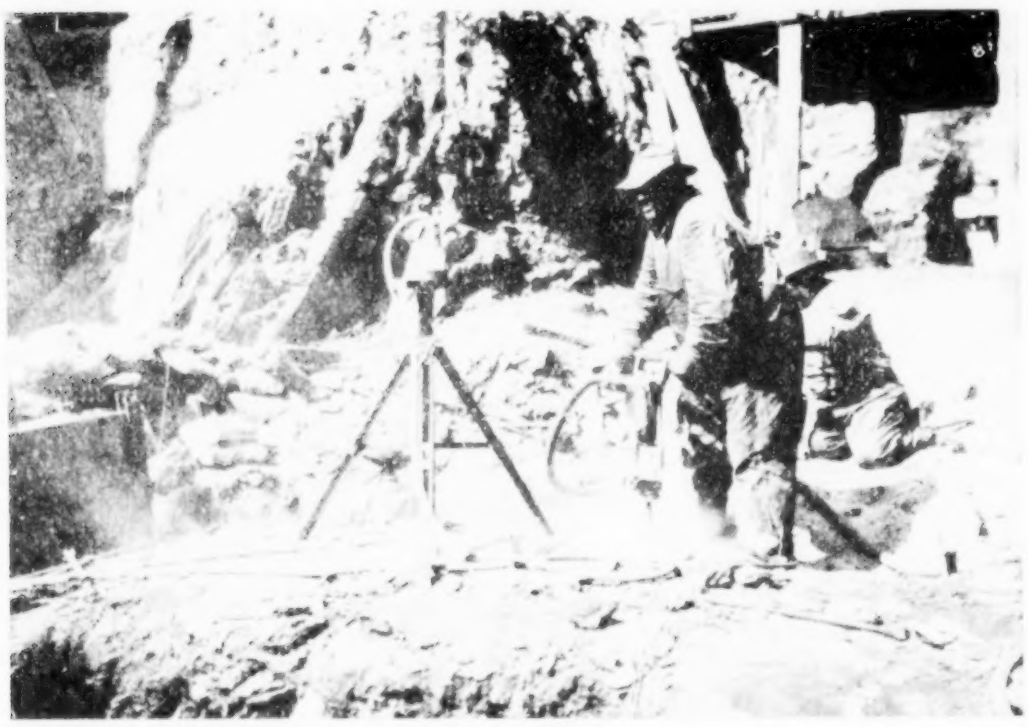

FIG. 5.—60th Street and Columbus Avenue. Air sample no. 17 taken beside jack hammer operator. (See Table 1.)

Comments

In order that the significance of Table 1 may be appreciated, the fol-

lowing comparison with similar studies is made. Winslow and Greenburg in their investigation of an ax grinding factory (8) obtained an average of 1,239,000,000 particles, under 10 microns, per cubic meter of air in thirty-two dust samples taken in a wet grinding shop, while ten samples in a dry grinding shop with good exhaust system gave an average of 16,222,500 particles per cubic meter. The same investigators (9) obtained an average of 6,392,400,000 particles per cubic meter in a sand blasting cabinet.[1]

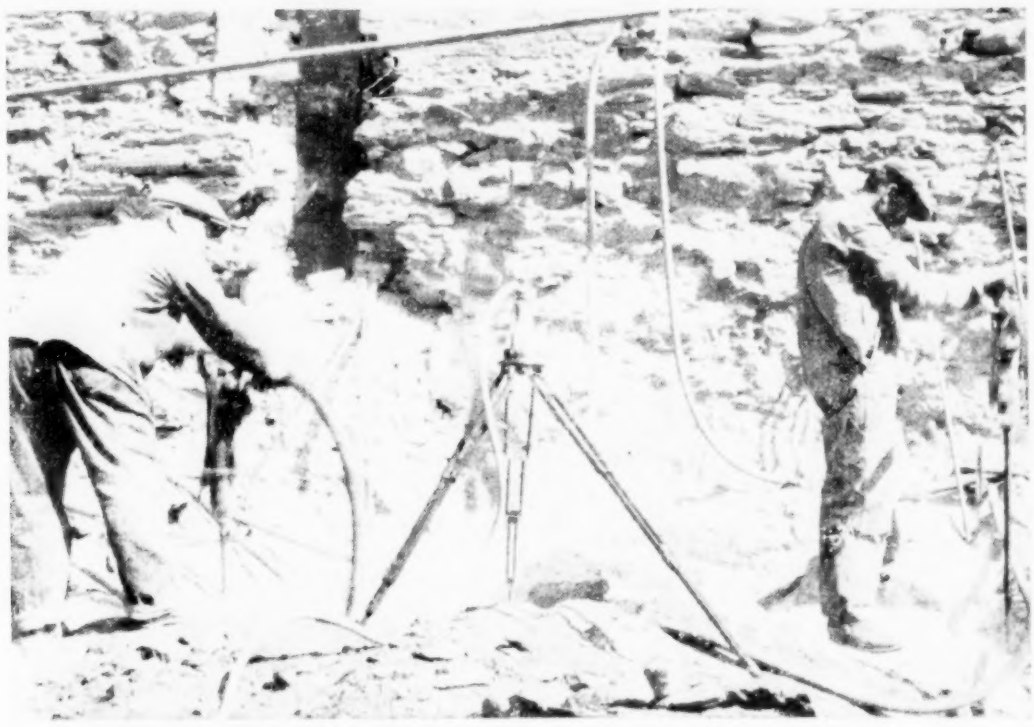

FIG. 6.—60th Street and Columbus Avenue. Air sample no. 18 taken between two jack hammer operators at line drilling along east wall. (See Table 1.)

FIG. 7.—53rd Street and Second Avenue. Air samples nos. 27 and 28 taken at heading on breathing level of five men operating water Leyners. (See Table 1.)

[1] These figures are obtained by converting the figures of Winslow and Greenburg,

Column III of Table 1, tabulating the number of dust particles, under 10 microns, per cubic meter of air, reveals a very considerable difference in the counts obtained. This difference is due primarily to the fact that most of these samples were taken in the open air, thus being influenced by the constant changes in the direction and the force of air currents. A number of samples yielded a higher count than those obtained in the very hazardous occupation of sand blasting, as referred to above, while only three counts were lower than in the dry grinding shop. Of these three samples, one, no. 28, was obtained by men operating a water Leyner, no. 29 was not obtained in a drilling operation, and no. 30 was a sample taken alongside of men shoveling. It is obvious that all these samples reveal air pollution to a dangerous extent, the only difference being one of degree. The harmfulness of silica dust is dependent on the proportion of small particles and, it is generally assumed, on the percentage of free silica which the dust contains. In the Joplin, Mo., district the amount of free silica in the dust is 90 per cent. or more; in the Broken Hill district of Australia free silica averages about 15 per cent.; and in the Butte, Mont., district the free silica in the dust varies from 50 to 60 per cent.

Figures 1, 2, and 3, reveal that 62, 78, and 98 per cent., respectively, of the dust particles in three typical samples, screened to 100 microns, were under 5 microns in size, while nearly all the particles were under 10 microns.

which are expressed in cubic feet, into cubic meters and *assuming* that the Greenburg-Smith impinger is three times as efficient as the Palmer water spray apparatus which these investigators used.

Granting that the free silica content is a reliable index of harmfulness, the results of the analyses, as shown in Table 1, indicate that, in the degree of harmfulness, the dust caused by drilling operations in New York City would occupy about a midway position between Broken Hill and Joplin, and would approximate the dust found in the Butte mines. It is evident, therefore, that men operating rock drills in New York City are exposed to a dust that is highly dangerous both from its high silica content, free or total, and from the excessive number of particles present under 10 microns in size.

The other columns of Table 1 detail the weight of dust and the weight of free and combined silica in the various samples and are informative when studied in comparison with the analysis of drilled rock in the last column.

Mavrogordato (10), on the basis of the extensive dust control experience in South African mines, states that when the mine dust had been reduced to 5 mg. per cubic meter, a great improvement in the incidence of silicosis was observed. He points out, however, that cases of silicosis are still occurring among men exposed to a concentration of about 2 mg. per cubic meter. On the basis of Mavrogordato's statement, column IV in Table 1 is illuminating; only one sample, no. 12, taken in the center of a lot, goes below 5 mg. per cubic meter and most of the samples, even those taken alongside of men operating Leyner drills, run very much higher. Even the weights of free silica, column V, Table 1, in the samples obtained at drilling operations, approximate or exceed the tentative standard of Mavrogordato given above.

Summary

Air samples of dust produced by rock drilling incident to building excavation and subway construction work were taken at eight locations in the central portion of New York City.

Analyses indicating the numbers of dust particles from 10 microns to the limit of visibility under the microscope, and chemical determination of the total and the free silica content of the rock dusts, were made according to accepted standard methods.

The free silica contents of the rock dusts were relatively high; the total dust particle counts, while varying, were large, and the smaller particles, those under 5 microns, predominated.

Conclusion

Rock drillers in New York City are exposed to dust which, both in silica content and in number and size of particles, is dangerous to health. Abundant evidence, obtained in numerous investigations over the world, has demonstrated such dust to be the cause of silicosis and tuberculosis.

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IV. CONCLUSIONS

THE findings reported in the preceding pages indicate that the hazards to which the workers are exposed are the result of exposure to silica rock dust in a concentrated form over an extended period of time.

Furthermore, excavation in the silicious rock of Manhattan and the Bronx, with the inevitable construction of new subways, tunnels, and tall buildings, seems destined to increase in unprecedented degree. Contracts

have recently been let for the construction, at a depth of 500 feet, of a water tunnel 20 miles in length, on which over 5,000 men will be employed during a period of six years, at a cost of $42,000,000. The necessity of safeguarding the lives of these men must be recognized before it is too late. The reduction to the greatest possible extent of the rock dust concentration and the shielding of the workers from inhaling the dust are two essentials.

Face masks of various kinds have in the past been recommended and given some trials, but they have been found unsatisfactory by the men for the type of work in which rock drillers and blasters are engaged. Other measures which have been recommended, some of which are being tried out, include (*a*) the prohibition by law of all dry drilling, making it compulsory for employers to discard the present dry jack hammer and supply the rock drillers with jack hammers having water supply attachments; (*b*) installation of dust and sludge collectors or attachments to drilling machines; (*c*) adequate ventilation in tunnel work; and (*d*) proper spacing of drillers so as to reduce the dust concentration in given areas.

As already indicated in this study, the substitution of wet drilling for dry drilling will not suffice to eliminate entirely the hazard of silicosis although it has been considered sufficiently important by authorities in other parts of the world to have been made compulsory. There is also some question as to the practicability of the wet drill in open cuts and excavations in times of freezing temperature. Dust collectors of various types have also been recommended and tried out, but such contrivances for trapping dust at the source have yet to prove their practicability under working conditions. The United States Patent Office reports that twenty-seven patents for dust and sludge collectors have already been issued. Wherever applicable, ventilation is the most important single measure for reducing dustiness. In view of the recognition of the fact that no one measure as yet known will adequately remove the hazard, it will undoubtedly be necessary to use all means thus far known to help in the reduction of the dust concentration.

Other measures which are of the utmost importance relate to the granting of compensation for silicosis. The recognition of this condition as an occupational disease under the Workmen's Compensation Law will do much toward early recognition of the condition and improvement in the methods of combating the disease. It is generally realized, however, that compensation for the occupational disease silicosis is more complicated than that for most other diseases on account of the prolonged latency and chronicity of the complaint. The diagnosis of silicosis of the lungs requires more skill and training in pulmonary diseases than is possessed by the average practitioner of medicine. Standards of diagnosis, proper classifications of degrees of injury, and other related matters are still to be established. Until these matters are fully studied out, there will be many difficulties in the way of adequately administering an occupational disease law which adds silicosis to the list of diseases for which compensation shall be granted.

J. I. H.
Feb., 1929

These defects and difficulties, however, should not stand in the way of some positive action. It would be most advisable for all interested groups, including the workers, the employers, the organizations which have conducted this study, the Bureau of Industrial Hygiene of the New York State Department of Labor, the American Association for Labor Legislation, and others having a vital interest in the subject, to take early action in order to frame the necessary legislation dealing with this problem.

V. RECOMMENDATIONS

1. Rock drilling, blasting, and excavating in New York City constitute a serious hazard to the health of the workers, owing to the constant exposure to silica dust, resulting in silicosis and tuberculosis. Remedial measures are urgently needed.

2. Efforts must be made immediately to improve markedly, by controlling the dust concentration, the conditions under which the men employed in these occupations are compelled to work.

3. Compensation should be granted by law for disability due to silicosis.

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BOOK REVIEWS

THE HUMAN FACTOR IN INDUSTRY. By *E. P. Cathcart*, C.B.E., M.D., F. R. S., Gardiner Professor of Chemical Physiology, University of Glasgow. Cloth. Pp. 114. London: Oxford University Press, 1928.

Although this small volume hardly reaches the same pitch of excellence as "The Human Machine" by F. S. Lee, yet, since ten years have elapsed since that was published, another effort to summarize information on the subject was due. Professor Cathcart uses nearly entirely the research work carried out by the Industrial Fatigue Research Board to illustrate the points that he makes. The material was put together originally as lectures to engineering students, and is certainly of value to works managers who cannot devote the time necessary to read and digest the scientific papers and reports in which the new knowledge has been presented.

The author is at his best when dealing with the physiology of activity and of fatigue, and with the means by which activity may be improved and the onset of fatigue postponed. He displays the influences exerted by hours of labor when well adjusted to energy output, by fitting workers physically to their work, and by practising good methods of applying force. He shows how output and also lost time due to sickness are affected by such environmental factors as ventilation, temperature, and lighting, or by well-designed machines. At times matters of more social interest are introduced, but here the author is not on his native heath.

This book must be found useful by anyone desirous of acquainting himself with the present position of knowledge with regard to industrial activity and fatigue.—*E. L. Collis.*

FITNESS FOR WORK. By *T. H. Pear*, Professor of Psychology, Manchester. Pp. 187. London: University of London Press, 1928.

In this book are presented certain thoughts relative to the motives which are held to actuate persons in regard to their day's work. Essentially the subject is approached from the psychologic aspect. Hence much discussion occurs about the exact meaning of words and less attention is given to acquired facts. A works manager, however, would rather be told the sequence of events which are associated with efficient work so that he may, by providing the necessary environment, insure a maximum of output in return for the wages paid, than be informed that a worker acquires, from using his muscles, a pleasure which may be termed sensuous. Careful reading of this little book does not convince that from the realms of psychology can come much light and leading to industry, certainly not so long as psychology deals with the abstract meaning of words rather than with any concrete series of observations and facts. The chapter devoted to laziness, with remarks on stupidity, has its appeal and originality, but gives no indication how to enlighten the stupidity of an operative or to avoid laziness in oneself.—*E. L. Collis.*

THE DERMATERGOSES OR OCCUPATIONAL AFFECTIONS OF THE SKIN. By *R. Prosser White*. Pp. 734. London, 1928.

This work has now reached its third edition which is twice the size of the second. The author has assembled for our use every reference to occupational skin trouble discoverable in literature, so that at times it is almost difficult to see the forest for the trees. Every page bristles with facts; one result of which is an index of unusual size, since it is composed of 224 pages out of the total of 734. There is more cohesion and order in the assembling of facts than was apparent in the earlier edition, and a commendable effort is made to group the various types of agents which cause skin trouble.

The author holds that, except for such skin troubles as result from general diseases, the personal factor or idiosyncrasy plays a subsidiary part in causation, which is generally determined by contact with some occupational hazard. Some idea may be gathered of the way in which the author attempts to classify these hazards by pointing to three groups: One contains agencies which remove oils or grease from the skin, leaving it so dry that it may crack and allow infection to occur from without; another contains strong solutions which dehydrate the cells and so cause tissue necrosis; while a third is composed of products of vegetable distillation, such as tars, which in time stimulate growths, such as warts, which may become malignant. The part played by injury, whether physical or chemical, in preparing the way for external infection is stressed. The form the infection takes may vary with the microbe concerned; hence the dermatitis resulting from the same agent may vary considerably. A point is made that moisture is practically necessary in every case; dry dirt is not harmful until it is moistened. Water itself, especially if distilled, is the most potent of all agencies in causing skin inflammation.

Throughout, references are given fully, while an excellent series of original illustrations adds greatly to the value of the book.—*E. L. Collis.*

THE SCHOOL AND THE WORKING CHILD. Being a Study of the Administration of Certain Laws Pertaining to Children in Industry, by Fifty School Departments of Massachusetts. By *Mary A. Clapp*, Investigator, Massachusetts Child Labor Committee, and *Mabel A. Strong*, Co-author of Child Labor in Massachusetts; Executive Secretary, Massachusetts Child Labor Committee. Cloth. Pp. x, 226 with index. Boston: Massachusetts Child Labor Committee, 1928.

This book constitutes the report of a study of the application of the Massachusetts state laws pertaining to children in industry, carried on during 1927 by the authors under the auspices of the Massachusetts Child Labor Committee. Fifty different communities of varying size within the state were visited and sufficient information collected to allow an appraisal of the efficiency of enforcement of the various laws. The time spent in each community did not, however, justify an opinion as to the value of the laws themselves or their effect on the health and welfare of the children concerned, and the authors wisely refrain from a discussion of this subject, although expressing their own opinion that further legislation is not needed.

The subject matter is well arranged and presented in such a manner as to be comprehensible to those unfamiliar

with the problem. One gains the impression that the investigators have been more than fair to the attendance officers, state inspectors, and physicians who are responsible for the administration of these laws, and they emphasize the difficulties which each encounters. The findings do show clearly, however, that the physical examinations required before issuance of employment certificates as now conducted are very inadequate, and are in many instances simply a farce. The authors also conclude that the school departments are lax in excusing children from school for home work without sufficient cause; and that there is particular laxity in the issuance of educational certificates. They also stress the importance of the continuation schools in the education program, and urge more attention for these from the school superintendents.

The criticisms and suggestions are well considered and seem to be justified by the findings. The book again reminds us that the enactment of comprehensive and intelligent laws to deal with a problem does not end the problem, but that attention must from time to time be focused upon their administration and application.—*Harold C. Stuart.*